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Abstract- The main objective of the research being conducted is, not only to achieve the required soil engineering properties by mixing this product but also to consider the effect of this product of soils stabilization on fine particles contained in lateritic and typically clayey soils. This research work presents the efficiency of calcium Silicate as an additive in improving the engineering characteristics of laterite aggregate soil and clayey soils. Investigations will be done to evaluate the effectiveness of this soil stabilizer which involved the use of calcium Silicate ($CaSiO3$) formula fixed by (Ndiaye et al, 2022). As a chemical additive the percentage of the binder will be respectively 4 and 6%.

These two types of soils are expected to be stabilized and their effectiveness will be observed from the expected results only in terms of strength and consolidation by constant rate of strain parameters like recompression index (Cr) and compression index (Cc).

Keywords: *soil stabilization, chemical additive, calcium silicate, unconfined compressive strength and consolidation by constant rate of strain.*

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STABILIZATIONOFASUBSAHARANLATERITESOILUSINGCALCIUMSILICATE

Strictly as per the compliance and regulations of:

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The results of the tests conducted in Oregon State University on laterite aggregate soil showed that the compression strength (UCS) gives a value of 1,4 MPa for SH85 treated samples against 1,5 MPa for Portland cement ones but with a minimum of strain, under alternating temperature conditions. However, this evolution is even more important on clay samples, reaching 1.01 MPa of stress for ''dry black clay'' against 0.44 MPa for the ''dried black clay'' as peaks. The alternating wet and dried conditions were crucial as well as the specimens sizes.

Keywords: soil stabilization, chemical additive, calcium silicate, unconfined compressive strength and consolidation by constant rate of strain.

I. Aim & Objective of the Work

The present work is aimed at assessing the effects of Calcium Silicate ($CaSiO_3$) in soil stabilization.

- We will be conducting an unconfined compressive strength test (UCS) on the laterite aggregate treated either by $CaSiO_3$ or by cement.
- We will also be conducting a Consolidation by constant rate of strain (CRS) test on the black clay treated samples, untreated red clay and untreated black clay. The strengths of soils and their compression parameters will be observed and compared.

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To fulfill the aim of this study, the following objectives have been framed.

1. To procure the 6% treated black clay soil with $CaSiO_3$.
2. To procure the 4% treated laterite with $CasiO_3$ and the 4% treated laterite with cement samples.
3. To procure the untreated black clay and the untreated red clay samples.
4. To study the results in term of UCS for laterite samples or in term of consolidation by CRS for the procured clayey samples.
5. To compare the performance of these soils when stabilized with Calcium silicate with the same soils when stabilized with Portland-cement.

II. Litterature

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).

(Latifi et al., 2015) have conducted a study on a treated tropical laterite soil with calcium-based powder stabilizer (commercial name Sh85 we studied as *$CaSiO_3$*). A series of compressive strength tests was performed to determine the strength performance of the treated soil. The strength test results showed that the Sh85 stabilized laterite soil was roughly five times stronger than the untreated soil at the seven days of curing period.

III. Methodology Adopted

- Firstly, aggregate soil samples have been collected from Senegal 02 sites (Bambey and Thiadiaye) in order to examine the elemental composition and the morphological images (see appendix). From where the Bambey laterite was chosen specifically from Ngoundiane pit.

– Secondly, sieve analysis test has been performed to determine each type of soil that we brought at the Oregon state university, Civil and Construction engineering facility.
– Once the mixture and compaction test were performed on the **laterite sieved at 0/20** to find out the optimum moisture content (OMC) at **10.2%** and Maximum dry density (MDD) at **2.06 g/cm^3**, and with obtained OMC and MDD:

- A certain concentration of calcium silicate (CaSiO3) has been fixed, mixed and compacted with each soil sample using standard molders 100/150 mm or 3.75' / 4.375'.
- The percentile of Calcium silicate is fixed to 4% added in the laterite specimen and 6% added in the black clay specimen soil, as which the studies have shown earlier.
- The unconfined compressive strength has been performed to find the unconfined compressive strength (UCS) of the laterite soil and the black clay treated soil.
- The consolidation part of test has been performed to evaluate the rate of compression for the untreated or treated black clay specimens and the untreated finest particles of clay found in the laterite specimen.

– Finally, the results are compared for each type with cement additives at the same percentiles.

IV. Expected Outcomes

It is expected that these soils specimens are stabilized, and their engineering properties are enhanced using that chemical additive at the appropriate content.

V. Results in UCS of Laterite Specimens

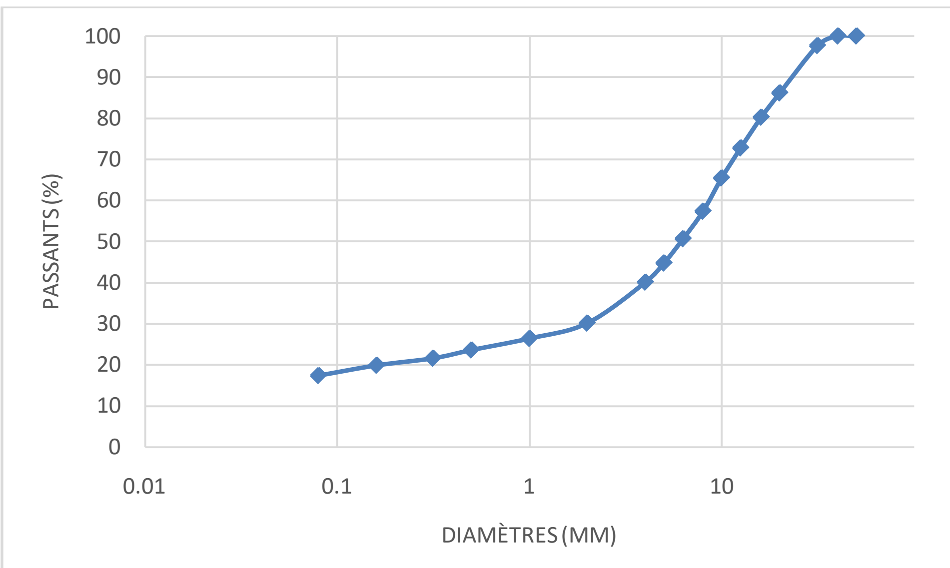


Figure 1: Particle size distribution curve of laterite

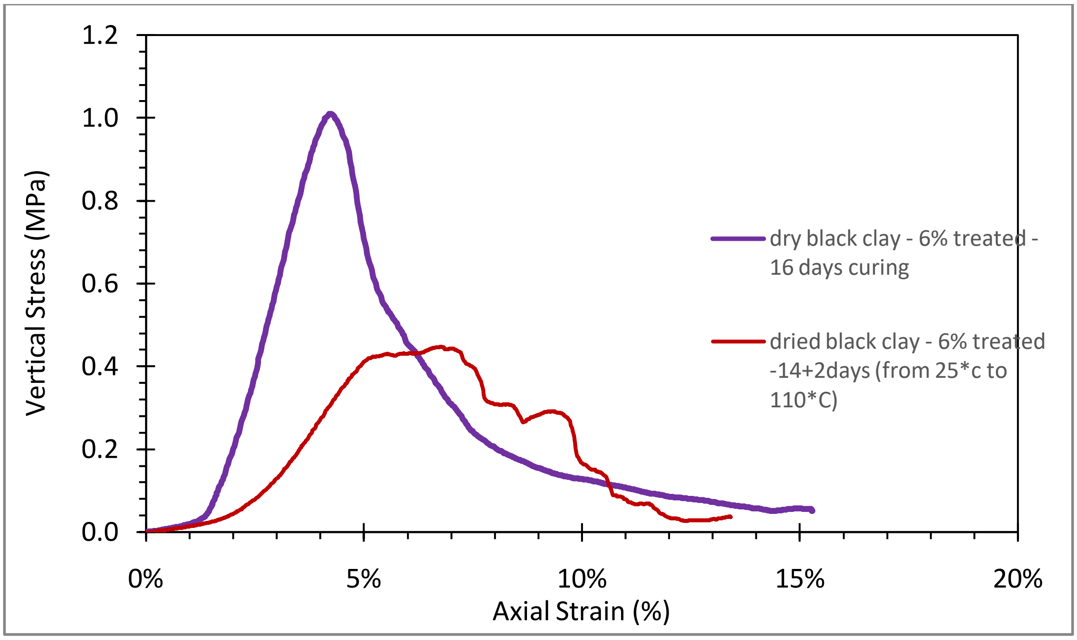


Figure 2: Evolution of the UCS of two (02) black clay specimens under different conditions

The analysis of the curve shows us a progressive evolution of the UCS of two (02) black clay specimens.

The ''dried black clay'' represents the specimen treated by 6% of CaSiO3 and after 14 days normal curing to which we added 2 days (24H in wet at 25*C and 24H in dry at 110*C).

The ''dry black clay'' curve represents the specimen treated by 6% of CaSiO3 and keeped in a dry conditions at 25*C during the same timing.

However, this evolution is even more important reaching 1.01 MPa of stress for ''dry black clay'' against 0.44 MPa for the ''dried black clay'' as peaks.

The black clay is a swelling material, consequently, its expansion in the presence of water weakens it and makes it unfit for construction (figure 2). The original swelling mechanisms of soils have been widely studied, but it is still difficult to establish a relationship between the progression of the issue and the time (Cisse and al., 2017).

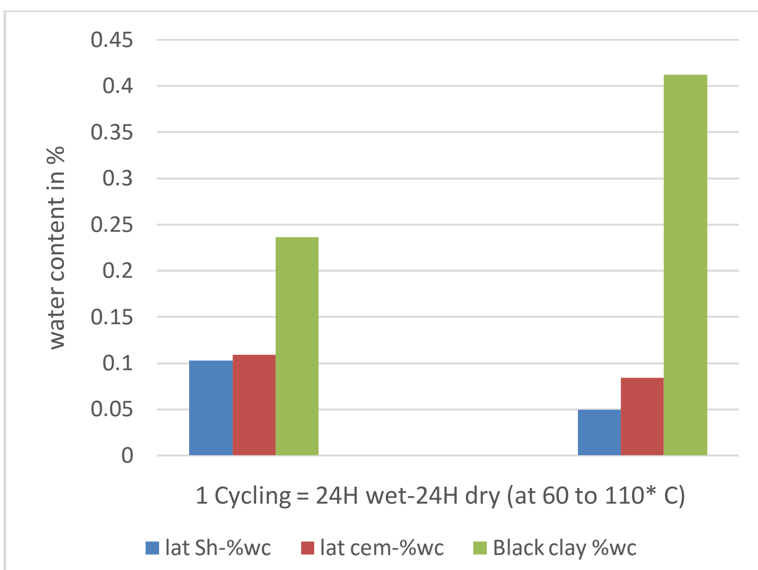


Figure 3: Water content per type of specimen (laterite 4% CaSiO3, laterite 4% cement and black clay 6% CaSiO3)

Alternating temperature between the wet environment at 25*C and the dried one at 110*C oven , during 2 cycles, showed the tendency of laterite samples treated with cement to absorb more water than those treated by calcium silicate (figure 3).

The black clay samples have showed much more absorbance even though they were treated at 6% with CaSiO3 and curing in that same process of alterning temperature.

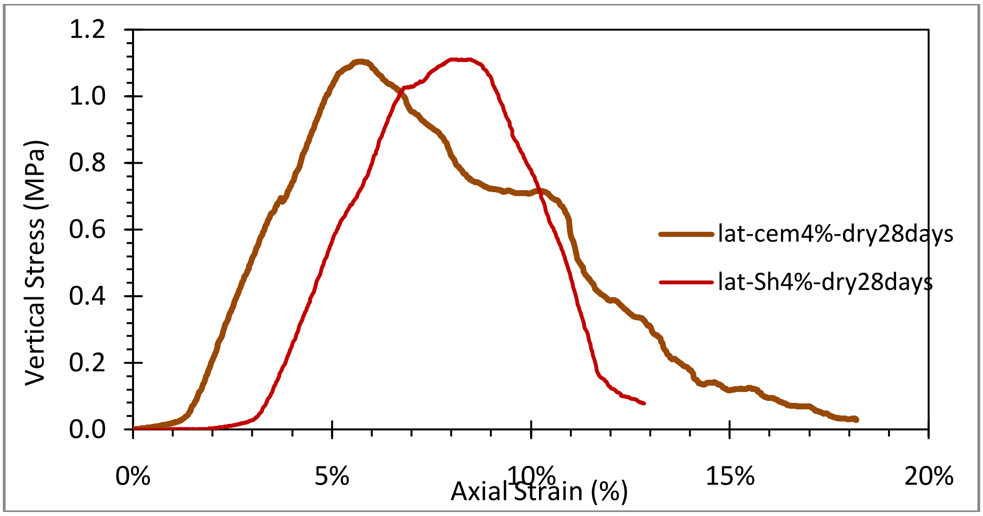


Figure 4: UCS of treated laterite samples after 28 days curing in dry and room conditions

Under room temperature (~25*C) and dry storage conditions, the laterite samples were crushed at 28 days, under these conditions (figure 4), the laterite treated with 4% cement (lat-cem4%-dry28days) reached a peak of 1.11 MPa with an elongation level of about 6% before collapsing to 18% elongation.

However, the calcium silicate-treated laterite (lat-sh4%-dry28days) in the same conditions, despite reaching 1.10 MPa with 8% elongation, only collapses to about 13% (figure 4).

But, this does not tell us much about the behavior in the natural environment with 3-4 months of rainfall out of 12.

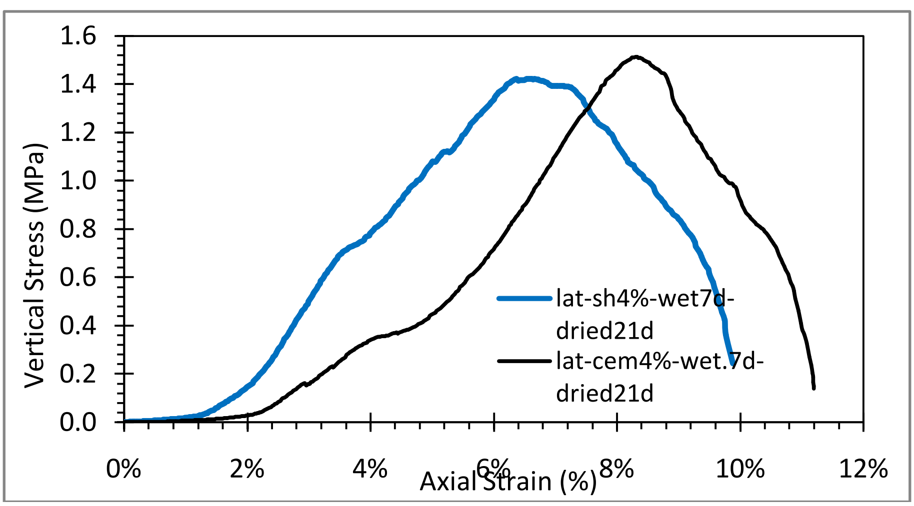


Figure 5: UCS of treated laterite samples after 28 days curing alterning a 24H storage in wet or a dried conditions

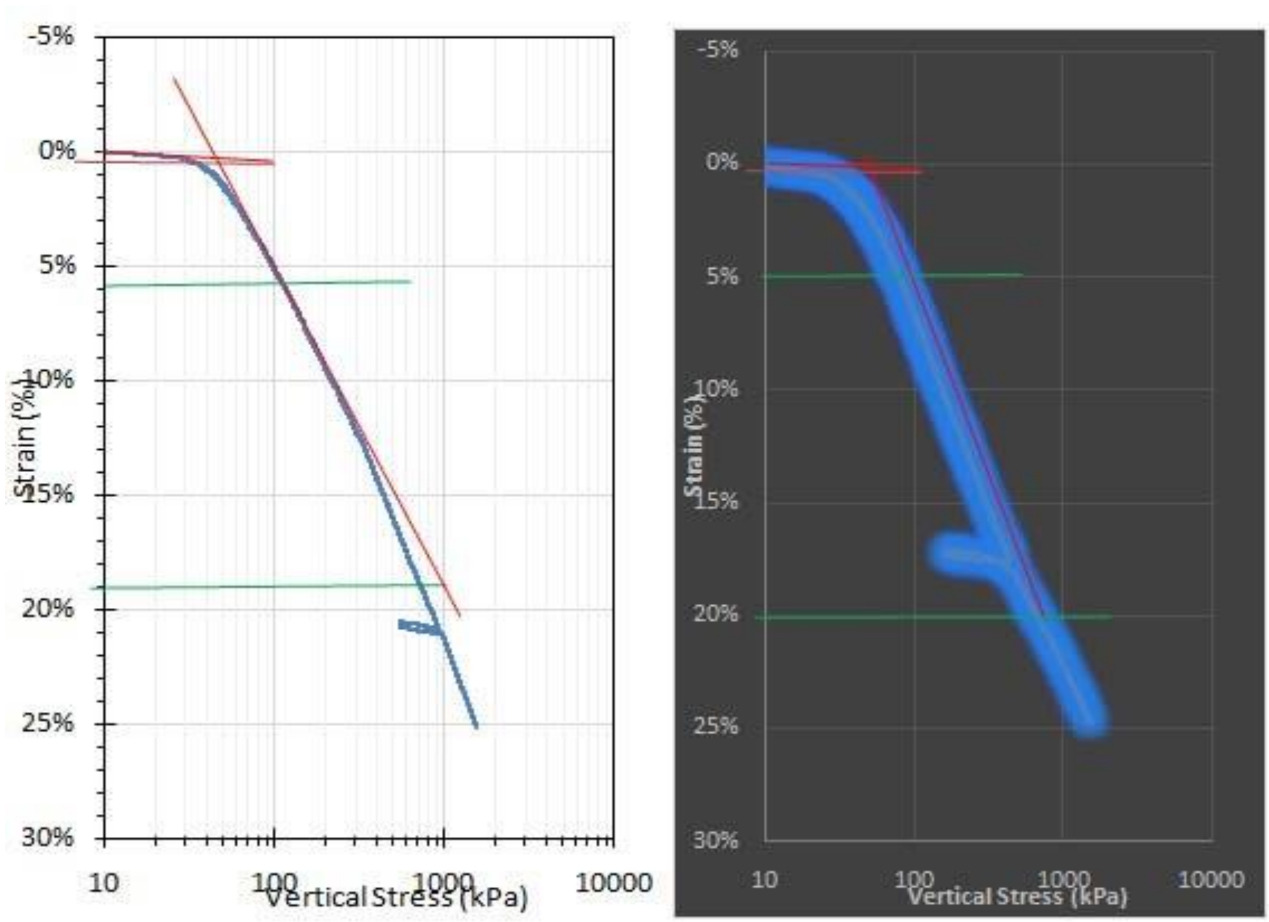
It was found that the **CaSiO3-treated laterite** reached its peak faster with a minimum elongation of about **6%** against **8.5%** for the cement-treated laterite, it collapsed well before the cement-treated laterite at about **10%** against **11%.**

Some complementary results in terms of consolidation rate for the untreated and the treated black clay samples once saturated can be used to support this thesis further.

VI. Results with a CRS of Consolidation for Treated and Untreated Clay Specimens

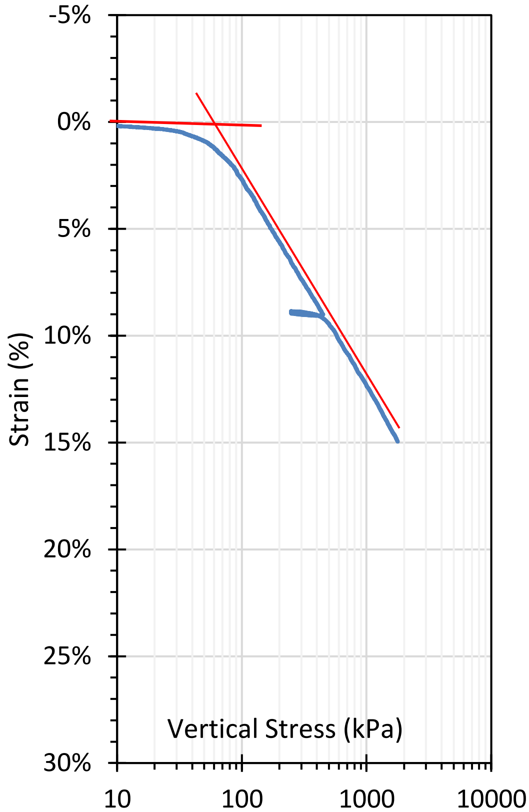
Table 1: Classification of Ngoundiane laterite

Characteristics	Latérite of Ngoundiane		Foundation 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
GTR Classification	B6			
USCS Classification	GC			



Curve (a): untreated black Cc=0.14 and Cr=0.005 *Curve (b):* treated black Cc=0.0875 and Cr=0.0025

Figure 6: Consolidation curves by oedometer of treated and untreated clays



Curve (c): untreated fine laterite Cr=0.0025 and Cc=0.100

Figure 6 *shows the strain, versus log stress, and the curve obtained from the oedometer test for both untreated and treated clay specimens of 6% CaSiO3 treated sample cured for 28 days.*

a) The values for untreated black clay of compression index, Cc and recompression index, Cr are 0.14 and 0.005, respectively.
b) While the Cc and Cr values for treated samples are 0.0875 and 0.0025, respectively.
c) Finally, the Cc and Cr values for untreated brown fine laterite specimen are 0.100 and 0.0025, respectively.

VII. Conclusion

Firstly, it was important to run the same UCS test carried out on samples treated with either cement or calcium silicate had to be carried out under alternating conditions of extreme temperature (heat transferred by a bituminous coating of about **110*C** for 24H) and relative humidity absorbance by capillary lift **at 25*C**.

It's shown that the specimen treated by cement absorbed much more water than the one treated by silicate.

Secondly, running the consolidation process, has shown that the compression index, Cc value of the treated black clay compared to the untreated black clay decreases by 0.0525, has indicated a significant improvement of the resistance to compressibility due to CaSiO3 treatment. Also, the water content percentile decreased from 47% to 44% after the consolidation process of the 02 specimens of black clay.

However, black clay has always been rejected in Senegal as a soil material that can support any construction. This study of its behavior in an environment of alternating heat and water makes it fragile and confirms its unsuitability for any use as a support soil or subgrade without other specific treatment.

Finally, 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.

Acknowledgements

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Appendice in Terms of Elemental Composition for Laterites

Calcium Silicate as a chemical additive is found that it will act as a good compaction aid between the soil particles, and it is very soluble in water. The images obtained by scanning electron microscopy (SEM) show the elemental composition of the most representative samples based on the percentile of atoms:

sample 1_site1_laterite(1)

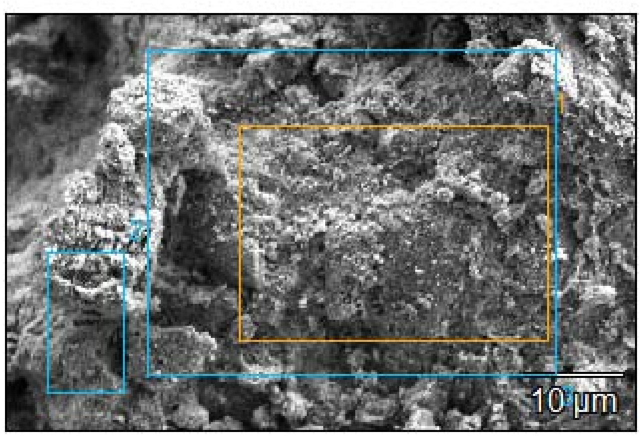

Figure 7: Image of the sample 1 as raw laterite from the Thiadiaye site

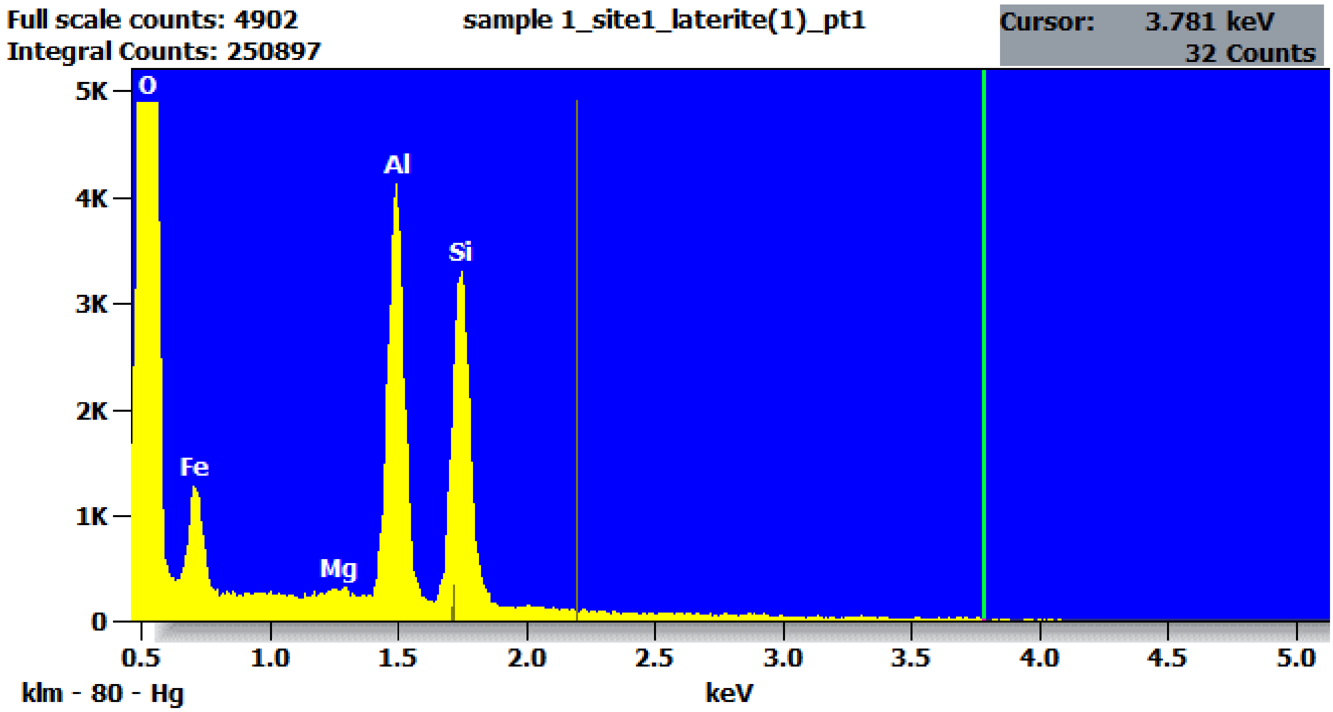

Figure 8: Elemental composition of the raw laterite from Thiadiaye site 1

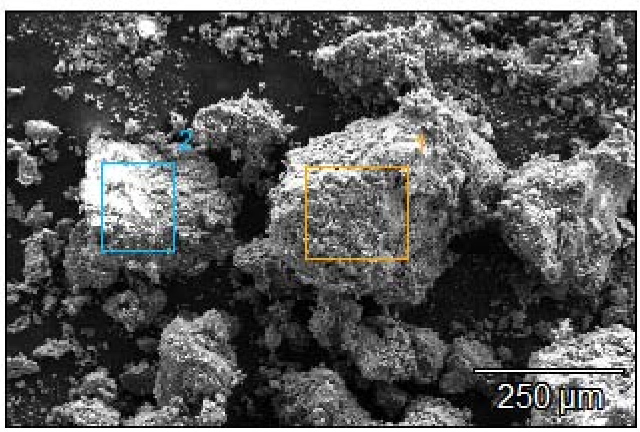

Figure 9: Image of the sample 3 compacted mix laterite from the Thiadiaye

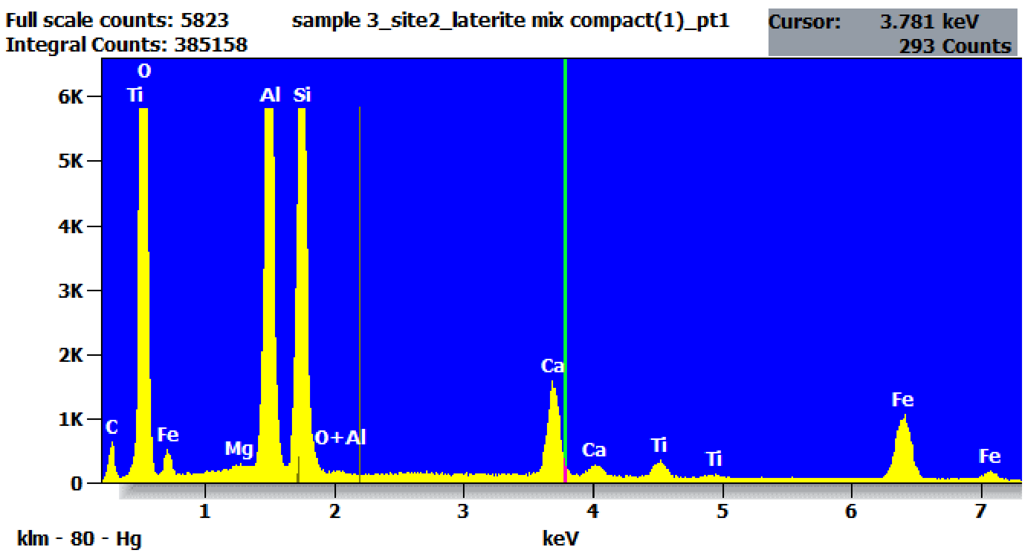

Figure 10: Elemental composition of the sample 3 compacted mix laterite from Thiadiaye

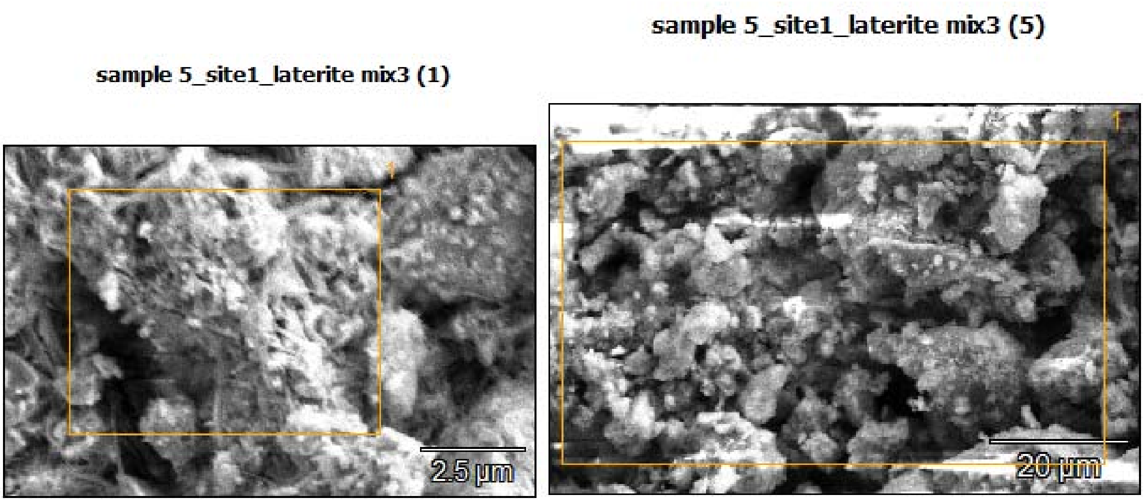

Figure 11: 2 images of the sample 5 of compacted mix laterite from bambey site

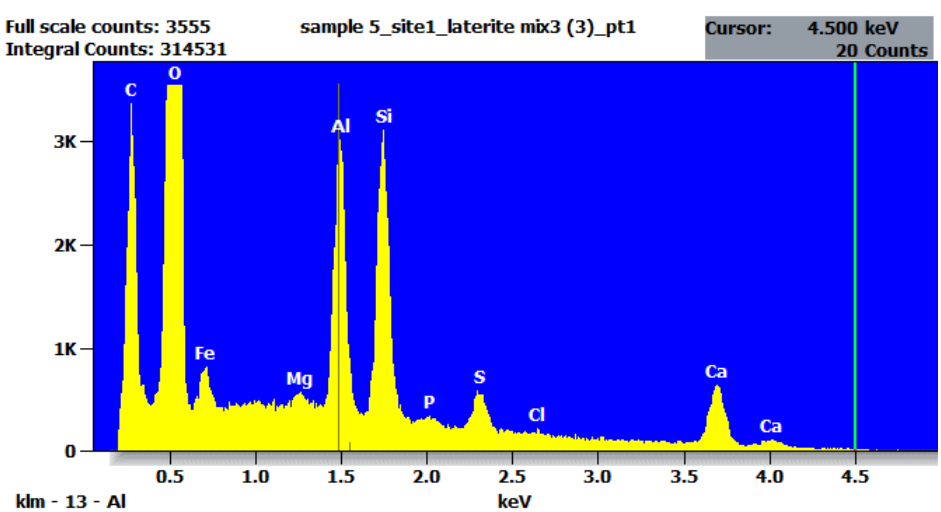

Figure 12: Elemental composition of the sample 5 compacted mix laterite from Bambey

sample 7_site1_binder (2)

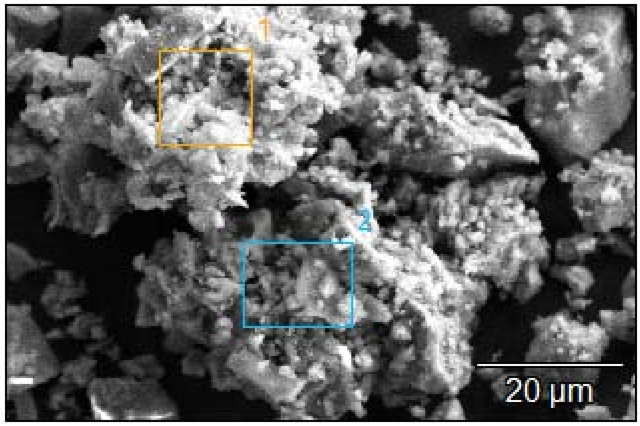

Figure 13: Image of the pure binder in powder as sample 7

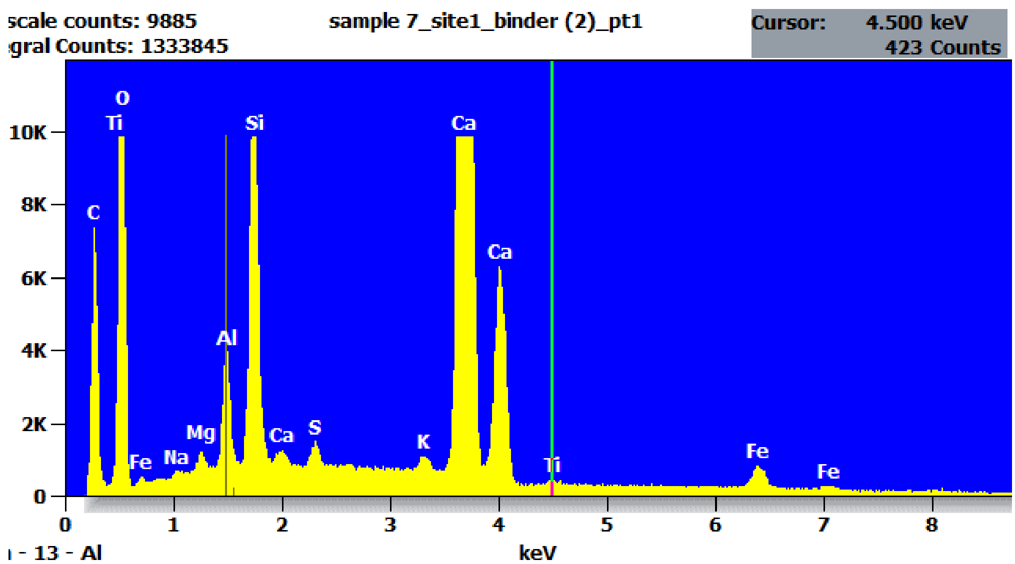

Figure 14: Elemental composition of the pure binder as sample 7

Tableau 1: Percentile of atoms in the pure binder as sample 7

	C	*O*	*Na*	*Mg*	*Al*	*Si*	*S*	*Cl*	*K*	*Ca*	*Ti*	*Fe*	*Cu*
sample 7_site1 _binder (2)_pt1	3.75	**30.40**	0.11	0.24	1.37	**5.71**	0.46		0.40	**54.40**	0.37	2.80	
sample 7_site1 _binder (2)_pt2	2.23	**39.19**		0.26	2.29	**3.76**	0.38	0.21	0.13	**46.78**	0.34	4.16	0.29