

Physicochemical, Mineralogical and Thermal Characterization of a Lateritic Clay from Toglou (Senegal) for Potential Use as a Reactive Clay in LC3 Cements

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DOI : <https://doi.org/10.52403/ijrr.20261026>

ABSTRACT

A lateritic clay from the Toglou deposit (Senegal) was characterized to evaluate its potential valorization in an LC3 (Limestone Calcined Clay Cement). The sample was analyzed by X-ray fluorescence (XRF) and quantitative X-ray diffraction (XRD, Rietveld method) to estimate its kaolinite content, by laser granulometry to measure its fineness after grinding (confirmed by an independent Blaine measurement), and by Atterberg limits and differential thermogravimetric analysis (DTG). The results show a kaolinite content of 46.1%, associated with 40.8% illite, i.e. a sum of phyllosilicate phases of 86.8%, with feldspars (albite and K-feldspar) totaling about 9.1% and a residual quartz and carbonate content below 4%. The SiO₂/Al₂O₃ ratio (1.44) and the Fe₂O₃ content (4.38%), both markedly higher than in a high-purity metakaolin, are discussed with regard to their influence on pozzolanic reactivity and the colour of the calcined product. The specific surface area, determined by air permeametry (Blaine, 947.8 ± 31.3 m²/kg), and the Atterberg limits

(LL = 44.8%; PI = 17.7%; USCS class ML) confirm a kaolinite/illite-type behaviour without smectite. DTG analysis, performed on three independent samples identified within a wider batch of eight Senegalese clay samples sent for thermal analysis, confirms a dehydroxylation domain consistently located between 500 and 560°C, principally associated with the dehydroxylation of kaolinite, although the relative intensity of this signal varied between samples. This domain provides a reference point for the study of thermal activation, but does not on its own define the optimal calcination temperature, which will need to be determined experimentally. These results place the Toglou clay within the 40-60% kaolinite range reported in the literature as favourable for good mechanical performance in an LC3 formulation after calcination, an aptitude that remains to be confirmed experimentally.

Keywords: calcined clay, LC3, kaolinite, Senegal, mineralogical characterization, low-carbon cement

INTRODUCTION

Reducing the carbon footprint of the cement industry is a major challenge for current climate policies, as the sector is responsible for about 7-8% of global anthropogenic CO₂ emissions, 60% of which originate from the chemical decarbonation of limestone during clinker production and 40% from the combustion required for firing [1]. LC3 (Limestone Calcined Clay Cement), a ternary binder combining clinker, calcined clay and limestone, developed notably through the work of Scrivener et al. [2], allows a reduction in clinker content of about 50% and in associated CO₂ emissions of about 30%, while achieving mechanical performance and durability comparable to, or even better than, those of ordinary Portland cement [3].

One of the main advantages of this technology lies in its ability to valorize kaolinitic clays of moderate purity, including those containing only 40-60% kaolinite, without significant loss of mechanical performance compared with a high-purity metakaolin [1]. This tolerance relies on a set of selection criteria commonly reported in the literature: a sufficient kaolinite content (40-60%), a low content of carbonates and free quartz, an absence or low proportion of smectitic phases, and well-characterized thermal behaviour allowing a reliable calcination protocol to be defined. Clays with a high montmorillonite (smectite) content require particular attention, as this mineral family is associated with higher water demand and drying shrinkage than kaolinite or illite [7]. This feature considerably widens the number of deposits potentially valorizable worldwide, including in regions without access to commercial metakaolin.

Senegal has several clay deposits distributed across its territory (notably in the regions of Dakar, Thies, Saint-Louis, Ziguinchor, Kaolack and Kedougou), with a national clay production of about 400,000 to 670,000 tonnes per year between 2017 and 2021 [4]. These deposits remain, however, poorly characterized with regard to the LC3 application, despite a growing regional

demand for detailed data on local clay sources to adapt formulations to the mineralogical specificities of each site [5]. Among these deposits, that of Toglou is the subject of the present article, which aims to directly contribute to filling this characterization gap.

This trend is part of a global industrial acceleration of LC3: by mid-2026, about 35 industrial-scale plants were in operation and as many under construction worldwide, for an installed capacity of about 15 million tonnes per year, according to a recent market study [5]. West Africa illustrates this transition concretely, notably with the commissioning in April 2026 of a flash calciner dedicated to LC3 in Tema (Ghana, 400,000 t/year) and the launch of commercial LC3 cement production in Cote d'Ivoire, driven by the high cost of imported clinker and the local availability of suitable raw materials - conditions largely shared by Senegal [6]. LC3 also shows increased resistance to chloride ion penetration, the main cause of reinforcement corrosion, a relevant technical advantage for structures in coastal environments, as is the case for a large part of Senegalese buildings along the Atlantic coast.

Despite the existence of numerous clay deposits in Senegal, data integrating chemical composition, mineralogical quantification, particle size distribution and thermal behaviour simultaneously remain limited for materials likely to be valorized in LC3 systems. The objective of this study is to comprehensively characterize the raw clay from Toglou - chemical composition, quantitative mineralogical composition, particle size distribution after grinding, physical properties, geotechnical properties (Atterberg limits) and thermal behaviour - in order to assess its suitability with regard to the selection criteria presented above, and to define the calcination parameters to be implemented in future formulation work.

MATERIALS AND METHODS

Sample origin and preparation

The studied clay originates from the Toglou deposit, located in the Thiès region (Senegal), near Sebikotane and Diamniadio. The sampling point is georeferenced in UTM coordinates (WGS84, zone 28N): X = 273,120 m E, Y = 1,625,800 m N, i.e.

approximately 14°41'47" N, 17°06'25" W. After drying and homogenization, the sample was ground prior to particle size analysis and the other physical tests, according to the protocol detailed in the following section.

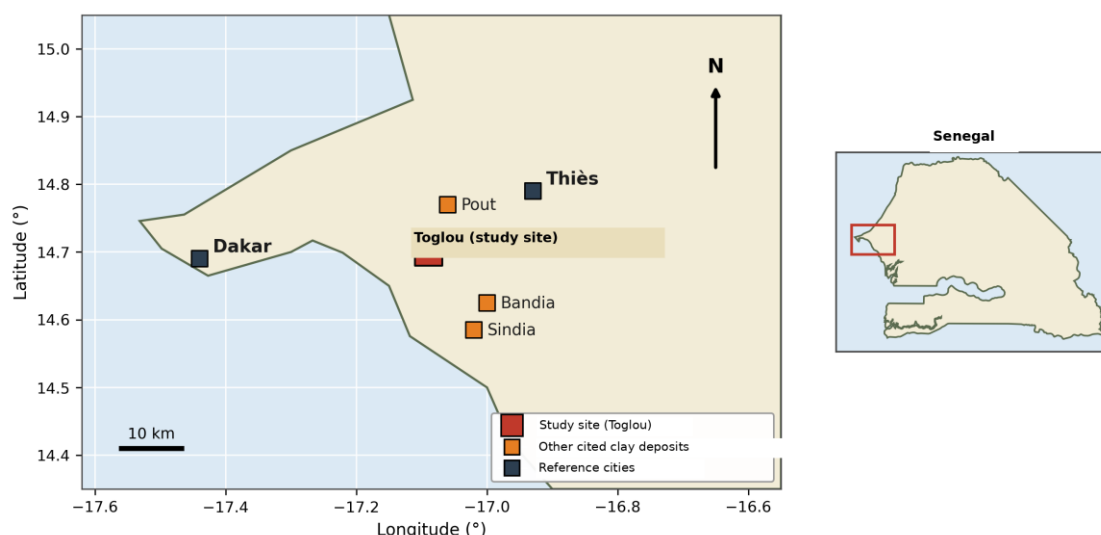


Figure 1. Location of the Toglou study site in the Thiès region (Senegal). Inset: location of Senegal in West Africa

Chemical analysis (XRF)

Elemental chemical composition was determined by X-ray fluorescence (spectrometer type 9900, ThermoFisher) at the SOCOIM chemistry laboratory. The pressed pellet is bombarded by a primary X-ray beam, generating secondary fluorescence radiation characteristic of each element present, detected by an argon/methane gas-flow transducer, allowing automatic calculation of elemental mass concentrations. The instrument's built-in CO₂ calculation module, calibrated for raw-meal or clinker-type matrices, is not applied to the characterization of raw clay feedstock; the mass loss associated with decarbonation and dehydroxylation is instead quantified through loss on ignition (LOI, see below).

Grinding

Grinding of raw materials is performed using a Retsch disc vibratory mill, for a 300 g charge and a fixed grinding time of 4 minutes. This protocol, applied identically to the clay, limestone and gypsum, homogenizes the fineness of the materials

prior to laser granulometry and X-ray fluorescence testing.

Mineralogical analysis (XRD)

Mineralogical composition was determined by X-ray diffraction using a D8 ENDEAVOR diffractometer (Bruker) at the SOCOIM chemistry laboratory, based on Bragg's law: $2d \cdot \sin(\theta) = n \cdot \lambda$. This method identifies the nature and structure of the crystalline phases present, in particular the kaolinite content. A key methodological limitation must be underlined: XRD only characterizes the crystalline phases of the sample and does not allow direct quantification of a possible amorphous fraction.

Laser granulometry

Particle size distribution was measured by laser diffraction using a Mastersizer 3000E granulometer (Malvern Panalytical) at the SOCOIM chemistry laboratory, in dry dispersion (Aero module, compressed air). This method is based on the measurement of the intensity of light scattered by particles in

suspension as a function of scattering angle, allowing the particle size and size distribution of the sample to be calculated after the 4-minute grinding step described above.

Real density (pycnometry)

Real density was determined by pycnometry at the SOCOCIM physics laboratory, using gasoline as the pycnometric liquid; this presents the advantage of not reacting with clay phases nor causing their swelling, in contrast to water.

Loss on ignition (LOI)

LOI was determined by calcination in a muffle furnace (Carbolite Gero) at the SOCOCIM chemistry laboratory. About 1 g of clay (mass M1) is weighed into a pre-tared crucible; the mass of the loaded crucible (M2) is recorded, then the assembly is heated to 950°C for 15-20 minutes. After cooling, the mass of the crucible and calcined sample (M3) is measured. LOI, expressed as a percentage, is calculated as: $LOI (\%) = [(M2 - M3)/M1] \times 100$.

Thermogravimetric analysis (TGA) and differential thermogravimetry (DTG)

Thermal behaviour was studied by simultaneous thermal analysis using an STA 449 F3 analyzer (NETZSCH). The principle relies on continuous recording of the mass variation of a sample (initial mass about 100 mg) as a function of temperature, raised from 30 to 1000°C at a heating rate of 10°C/min, under an inert nitrogen atmosphere (20 mL/min protective flow, 20 mL/min purge flow). The mass-loss curve (TGA) is then differentiated with respect to temperature, revealing as peaks the temperatures at which the main mass-loss reactions occur. To verify the reproducibility of the thermal response of the deposit, the clay of Toglou was included, together with other Senegalese clay samples, in a batch of eight clay samples sent to the Vicat laboratory in France, at SOCOCIM's request. Three samples from this batch were identified a posteriori, from the order reference, as originating from the Toglou

deposit (Toglou Fosse N°1, Toglou N°4, Toglou N°1) and were retained for the reproducibility analysis presented in the Results section.

Atterberg limits (LL, PL, PI)

Liquid limit (LL) and plastic limit (PL) were determined according to standard NF P94-051 at the PrimoLab laboratory. The material is first sieved at 0.4 mm then mixed with water until a homogeneous paste is obtained. For the liquid limit, the paste is placed in the Casagrande cup, a standardized groove is cut, and the apparatus is operated until the groove closes; the number of blows required is recorded and a sample is taken at the closure zone for water content determination (24 h oven-drying at 105°C). The test is repeated for several water contents to establish the relationship between blow count and water content, the liquid limit being conventionally taken as the water content at 25 blows. For the plastic limit, a portion of the same material is rolled into a cylindrical thread until it reaches 3 mm in diameter; the plastic limit is reached when the thread crumbles at this diameter, the retained value being the average of several determinations. Water content is calculated as $w = (M_h - M_s)/M_s \times 100$, where M_h and M_s denote the mass of the wet and oven-dried material, respectively. The plasticity index is then calculated as $PI = LL - PL$.

Blaine specific surface area

Specific surface area was also determined by air permeametry according to standard NF EN 196-6, using a semi-automatic ACMEL LABO Blainemeter (BSA II) at the SOCOCIM chemistry laboratory. The sample mass to be weighed is calculated automatically by the instrument from the real density measured by pycnometry and the volume of the cell used (cell 11/20, 1.863 cm³), the powder bed porosity being fixed at the conventional value $n = 0.5$. After loading the sample into the cell, the time required for air to pass through the compacted bed is measured automatically, from which the instrument derives the mass-specific surface

area, reported at 20°C. The value reported by the instrument corresponds to the average of the measurements performed.

RESULTS

Chemical Composition (XRF)

Table 1: Chemical composition of raw Toglou clay (XRF)

Oxide	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	SO ₃	Cl	Na ₂ O
Content (%)	39.39	27.43	4.38	2.48	1.97	0.07	0.09	0.01	0.03

The sum of oxides reported in Table 1, complemented by the experimentally measured LOI (11.25%), totals 87.1%, leaving a residual gap of about 12.9% unexplained by the currently quantified species. This gap reflects the fact that the initial XRF balance is expressed on an incomplete analytical basis: the silica content it reports (39.39%) does not necessarily represent the actual content of the sample, but the fraction quantified by the instrument under the calibration conditions used. Such a discrepancy is consistent with a well-documented phenomenon in pressed-pellet XRF: light elements (Si, Al, Na, Mg), whose fluorescence is more sensitive to matrix, particle size and sample preparation effects than that of heavier elements (Ca, Fe, K), are more exposed to under-quantification when the instrument calibration - optimized for a raw-meal-type cement matrix - is applied to an aluminous clay such as Toglou, whose composition departs markedly from the usual calibration range. A re-analysis with a calibration adapted to clay matrices, or failing that the acquisition of the complete

raw XRF report, would remain desirable to precisely confirm the extent of this bias before definitive integration into a future version of this article.

In accordance with the analytical laboratory's recommendation, the chemical composition of Toglou clay is also presented on a basis normalized without loss on ignition. The sum of the six major oxides quantified by XRF (Table 1) being 75.72%, a normalization factor of $88.75/75.72 = 1.17208$ was applied to bring this sum to 88.75%, corresponding to 100% minus the experimentally measured loss on ignition (LOI = 11.25%). LOI is kept separately at its measured value, without being itself renormalized. This normalization does not constitute a new experimental measurement: it expresses the relative proportions of the quantified oxides on an analytical basis consistent with the measured LOI, without prejudging the exact nature of the fraction not represented in the initial XRF balance. The raw values of Table 1 remain the reference for all calculations and discussions in this article.

Table 2. Normalized chemical composition of Toglou clay on a loss-on-ignition-free basis

Constituent	Raw XRF (%)	Normalized XRF (%)
SiO ₂	39.39	46.17
Al ₂ O ₃	27.43	32.15
Fe ₂ O ₃	4.38	5.13
CaO	2.48	2.91
MgO	1.97	2.31
K ₂ O	0.07	0.08
Total oxides	75.72	88.75
Loss on ignition (measured)	n.d.	11.25
TOTAL	86.97	100.00

The mass ratio SiO₂/Al₂O₃ of the sample is 1.44, a value markedly higher than the theoretical ratio of pure kaolinite (about 1.18). This ratio should not be overlooked in interpreting the pozzolanic potential of the

clay: an excess of silica, generally associated with the presence of free quartz, feldspars (albite, K-feldspar) or with the contribution of non-kaolinitic silicate phases such as illite. Feldspars, quantified by XRD at about 9.1%

of the mineralogical composition (see Mineralogical Composition below), constitute in this regard a notable contribution, larger than that of free quartz (3.33%), and should therefore be considered on the same footing as the latter in the interpretation of this ratio. This ratio alone does not allow quantification of the fraction of silica actually reactive after calcination; only XRD allows this silica to be attributed to identified crystalline phases (free quartz, feldspars) rather than to the kaolinite or illite sheets themselves.

The Fe₂O₃ content (4.38%) is also a parameter not to be overlooked: while iron

does not prevent the valorization of the clay in LC3, it influences the colour of the calcined product, which tends toward red-brown hues due to the formation of iron oxides during thermal treatment. This value remains moderate compared with the variability reported in the regional literature: Adeniyi et al. [7], on five Nigerian kaolinitic clays, measured Fe₂O₃ contents ranging from 0.10% to 8.51%.

Mineralogical Composition (XRD, Rietveld Refinement)

Table 3. Quantitative mineralogical composition of Toglou clay (XRD, Rwp = 18.21%, Rexp = 3.03%)

Phase	Kaolinite	Illite	Quartz	Albite	K-feldspar	Dolomite	Pyrite	Other
Content (%)	46.07	40.77	3.33	6.05	3.07	0.41	0.29	0.00

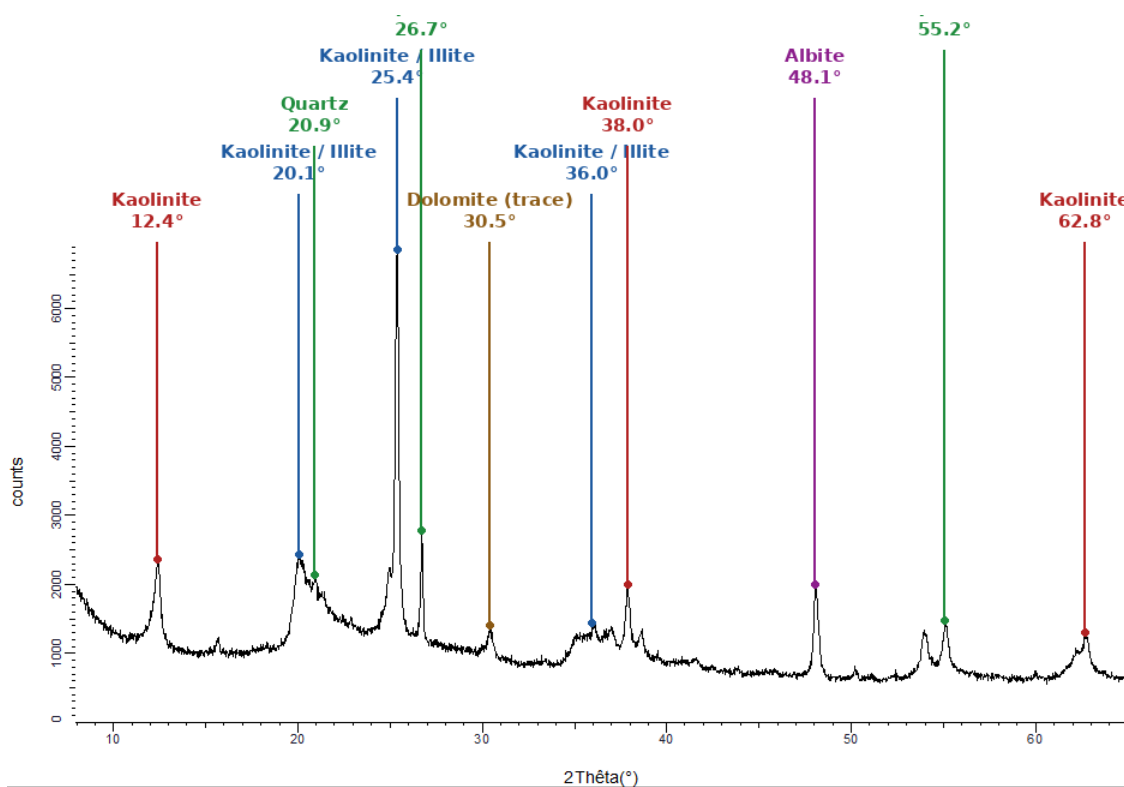


Figure 2. XRD diffractogram of Toglou clay with indicative attribution of the main peaks to the phases quantified by Rietveld refinement (kaolinite, illite, quartz, albite, dolomite). K-feldspar (3.07%), also quantified by refinement but without a clearly distinct

The sum of phyllosilicate phases (kaolinite + illite) reaches 86.8% of the quantified mineralogical composition. Feldspars (albite 6.05%; K-feldspar 3.07%), totaling about 9.1%, constitute the main accessory phase, well ahead of quartz (3.33%); carbonate

phases remain nearly absent (calcite, siderite, ankerite and anorthite not detected; dolomite at 0.41%). With a kaolinite content of 46.1%, Toglou clay falls within the 40-60% range reported in the literature as favourable for good mechanical performance in an LC3

formulation after calcination, the relationship between calcined kaolinite content and compressive strength being nearly linear up to this plateau [1]. The concurrent presence of illite in comparable proportion (40.8%) deserves attention: although less reactive than metakaolinite after calcination, calcined illite retains a partial pozzolanic potential documented in recent work. This mineralogical profile, with kaolinite and illite in comparable proportions and quartz and carbonates nearly absent, strikingly matches that of the low-purity Cuban clay studied by Alujas et al. [11], composed of about 40% kaolinite and 40% 2:1 minerals, a

clay which, once calcined, proved to be a highly reactive pozzolan source. This convergence reinforces the relevance of the Toglou deposit for a similar valorization. Fernandez et al. [12], directly comparing the pozzolanic reactivity of calcined kaolinite, illite and montmorillonite, confirm that although calcined illite remains less reactive than metakaolinite, its thermal decomposition nonetheless contributes, in mixed systems such as Toglou, to a partial amorphization beneficial to the properties of the final binder.

Particle Size Distribution After Grinding

Table 4. Particle size parameters of Toglou clay after 4 minutes of grinding

D (10)	D (50)	D (90)	D [3,2]	D [4,3]	Span
1.62 µm	13.7 µm	104 µm	4.70 µm	34.9 µm	7.47

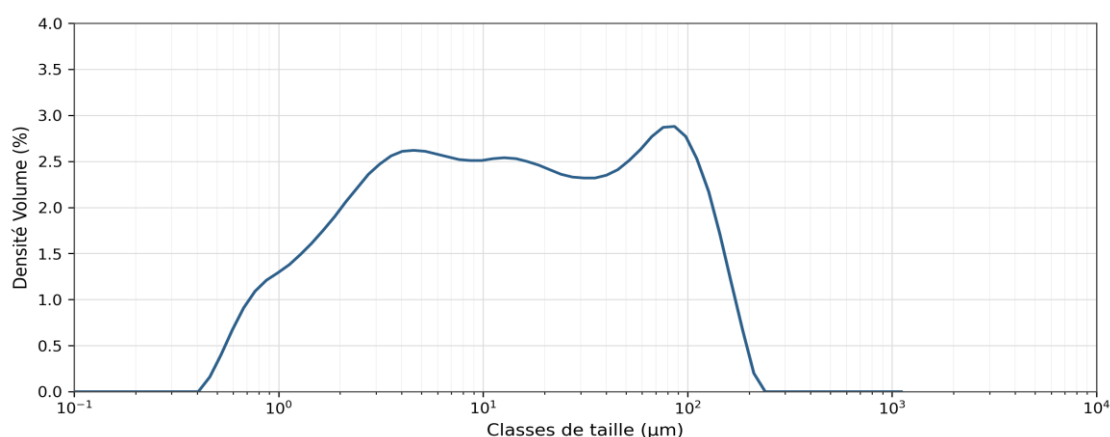


Figure 3. Particle size distribution of Toglou clay after 4 minutes of grinding

The distribution obtained after this 4-minute grinding step, determined by laser diffraction in dry dispersion (Aero module, compressed air), shows a bimodal profile, with two distinct modes separated by a moderate trough: a first mode centred around 3-5 µm, attributable to the fine clay fraction (kaolinite and illite sheets), and a second, broader mode centred around 75-90 µm, likely associated

with aggregates of fine particles not fully disaggregated by grinding or with the coarse quartz and feldspar fraction identified by XRD. The high span value (7.47) confirms the strongly spread-out nature of this distribution.

Physical Properties

Table 5. Additional physical properties of Toglou clay

Parameter	Real density	Specific surface (Blaine)	Loss on ignition (950C)
Value	2.605 g/cm ³	947.8 +/- 31.3 m ² /kg	11.25%

The measured real density (2.605 g/cm³) is consistent with a kaolinite-illite mixture. Specific surface area was determined by air permeametry (Blaine, NF EN 196-6), giving

a mean value of 947.8 +/- 31.3 m²/kg (mean value as reported by the instrument). The complete particle size distribution (D10, D50, D90, D [3,2], D [4,3], span) is presented

in Table 4; a specific-surface estimate derived from this distribution by the laser granulometer software is deliberately not retained in this article, a verification of the calculation parameters (in particular the

density used by the software) remaining necessary before it can be reliably used.

Atterberg Limits

Table 6. Atterberg limits of Toglou clay (NF P94-051)

Liquid limit (LL)	Plastic limit (PL)	Plasticity index (PI)	Indicative USCS classification
44.8%	27.2%	17.7%	ML (low-plasticity silt)

The liquid limit (LL = 44.8%), the plastic limit (PL = 27.2%) and the resulting plasticity index (PI = 17.7%) are consistent with a clay dominated by kaolinite and illite, in the absence of smectite, in agreement with the mineralogical composition determined by XRD. On the Casagrande chart, the (LL, PI) pair plots slightly below the A-line, which would classify the sample as a low-plasticity silt (ML) in the strict USCS sense, rather than a clay (CL) - a behaviour frequently reported for kaolinitic clays despite their phyllosilicate nature, and which is not inconsistent with their suitability for LC3 valorization.

Thermal Behaviour (DTG) and Reproducibility

To assess the representativeness and reproducibility of the thermal behaviour of the deposit, three distinct samples of Toglou clay (Toglou Fosse N°1, Toglou N°4, Toglou N°1) were retained for DTG analysis, identified within a batch of eight Senegalese clay samples sent to the Vicat laboratory in France. The three curves obtained show a dehydroxylation domain consistently located

between 500 and 560°C, principally associated with the dehydroxylation of kaolinite, but with a variable relative intensity depending on the sample: the dehydroxylation peak reaches about -1.0%/min for sample Toglou N°1, versus about -0.3%/min for Toglou Fosse N°1 and Toglou N°4. A moderate first endothermic signal, between 80 and 180°C, attributable to the release of free and adsorbed water, is also present in the three samples, with an intensity that is also variable - particularly marked for sample Toglou Fosse N°1 (up to about -1.5%/min), which could reflect a difference in residual water content at the time of testing rather than a mineralogical difference. The concordance of the dehydroxylation domain observed for the three Toglou samples suggests a certain stability of the thermal behaviour within the analyzed samples. The differences in signal intensity, however, indicate variability between samples, whose origin could be related notably to their mineralogical composition and physical state, without constituting proof of complete reproducibility of the thermal behaviour at the deposit scale.

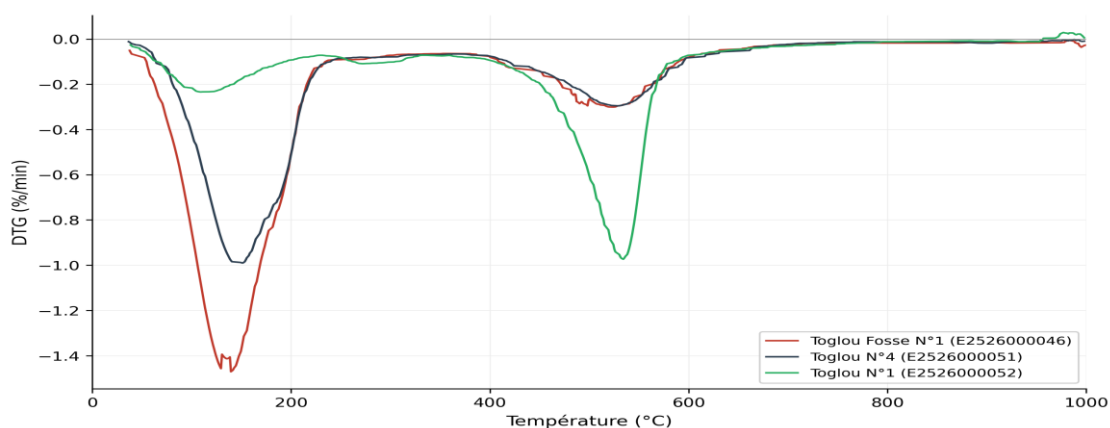


Figure 4. DTG curves of the three samples of Toglou clay identified within the pooled thermal analysis batch (Vicat laboratory, France)

This dehydroxylation domain (500-560°C) corresponds to the domain principally observed by thermal analysis. It constitutes a reference point for the study of the thermal activation of Toglou clay, but does not on its own define the optimal calcination temperature, which will need to be determined experimentally. This temperature range falls within the range generally reported for tropical kaolinitic clays: Adeniyi et al. [7] report main mass losses between 390 and 700°C on Nigerian kaolinitic clays, while Alujas et al. [11] show, on a Cuban clay of similar mineralogical composition, that maximum pozzolanic reactivity is reached for calcination at 800°C, this compromise between structural disorder and available specific surface constituting the best operating point beyond the sole dehydroxylation temperature measured by

DTG. In line with recommendations from the literature on calcined clays, several temperatures bracketing this domain (for example 600, 700 and 800°C, with a 1-2 hour hold) should be tested to identify the temperature leading to maximum pozzolanic reactivity, a compromise to be found between complete dehydroxylation of kaolinite and prevention of the recrystallization of less reactive phases at the highest temperatures.

For context, the clay of Toglou was part of a wider batch of eight Senegalese clay samples sent together for DTG analysis, including samples from the Badi, Tchiky and Sebikhotane deposits, which are not treated in the present article. Figure 5 presents the DTG curves of all eight samples for reference.

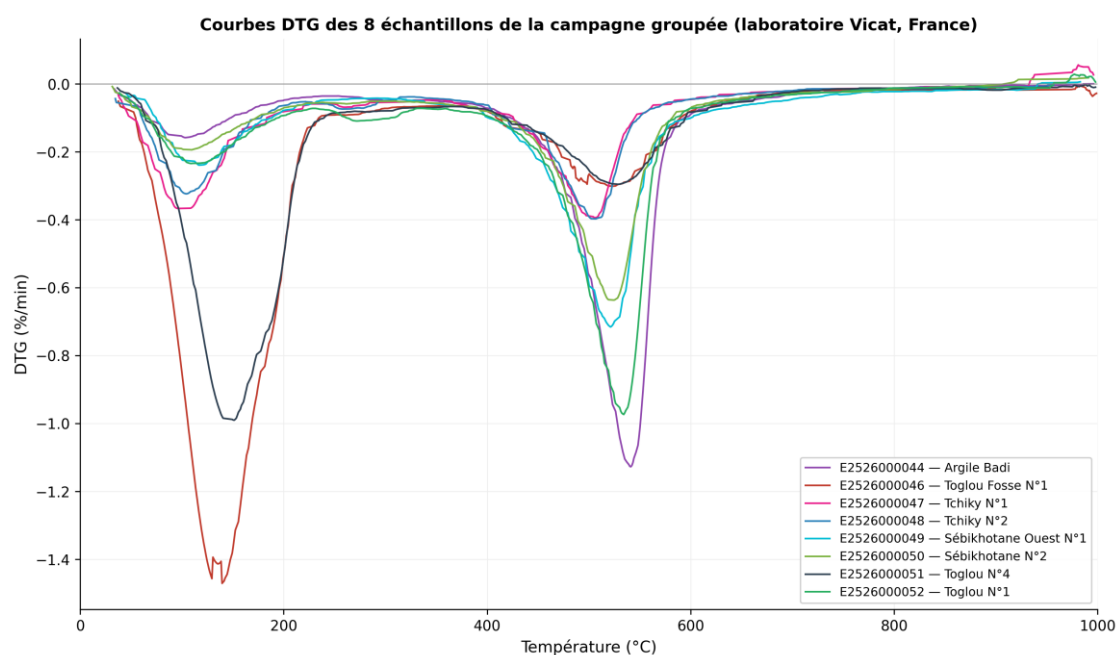


Figure 5. DTG curves of the eight samples of the pooled batch sent to the Vicat laboratory (France), presented for context. Besides the three Toglou samples (Figure 4), this batch included clay samples from the Badi, Tchiky and Sebikhotane deposits, not treated

DISCUSSION

The overall set of results converges toward a favourable diagnosis regarding the potential of Toglou clay for LC3 cement production. Its kaolinite content (46.1%), together with a high total phyllosilicate fraction (86.8%) and a very low residual carbonate content, places it directly within the composition range

reported in the literature as favourable for obtaining, after calcination, interesting mechanical performance - this suitability remaining to be confirmed experimentally. The SiO₂/Al₂O₃ ratio (1.44) and the Fe₂O₃ content (4.38%), while not calling into question the feasibility of valorization, constitute parameters to be integrated into the

analysis: the former as an indirect indicator of a potentially poorly reactive silica fraction - to which feldspars contribute more than free quartz - the latter as a factor of coloration of the calcined product. The concordance of the dehydroxylation domain (500-560°C) observed across the three Toglou samples sent to France, despite a variable relative intensity, supports the reliability of this domain as a reference point for the calcination protocol to be investigated in future experimental work, although it does not on its own define the optimal calcination temperature. Specific surface area was determined by Blaine measurement (947.8 +/- 31.3 m²/kg), the complete particle size distribution being also available. The geotechnical characterization (Atterberg limits) confirms this mineralogical reading: a liquid limit of 44.8%, a plastic limit of 27.2% and a plasticity index of 17.7% are typical of a kaolinite/illite clay without smectite. Overall, comparison with Senegalese clays of similar geological context and with low-to-medium-purity kaolinitic deposits already documented in the international literature - Cuba [11], Nigeria [7] and, more broadly, the European panel compiled by Danner et al. [8] - places Toglou clay among deposits presenting a good compromise between availability, kaolinitic purity and low carbonate impurity content, its moderate iron content not constituting an obstacle to its valorization.

CONCLUSION

The physicochemical, mineralogical and thermal characterization of Toglou clay (Senegal) allows three levels of conclusion to be distinguished, proportionate to the level of evidence provided by each type of result. What is directly demonstrated by the tests performed: Toglou clay contains 46.1% kaolinite and 40.8% illite (XRD, Rietveld refinement), i.e. a sum of phyllosilicate phases of 86.8%, with feldspars (about 9.1%) as the main accessory phase and a negligible carbonate content; its Atterberg limits (LL = 44.8%; PI = 17.7%) confirm this

mineralogical reading, typical of a kaolinite/illite clay without smectite.

What the results strongly suggest: the thermal response by DTG, whose dehydroxylation domain position remains consistent across three independent samples despite a variable relative intensity, shows a main dehydroxylation domain principally associated with kaolinite between 500 and 560°C. This domain constitutes a reference point for the study of thermal activation, but does not on its own define the optimal calcination temperature, which will need to be determined experimentally in the continuation of the experimental program.

What remains to be demonstrated: the effective pozzolanic reactivity of the calcined clay, the calcination temperature optimizing this reactivity, as well as the mechanical performance and durability of an LC3 cement produced from this clay, have not yet been evaluated experimentally and will be the subject of future work.

Declaration By Authors

Acknowledgement: The authors thank the physics and chemistry laboratories of SOCOCIM Industries, the Vicat laboratory (France) and PrimoLab for performing the analytical tests presented in this article.

Source of Funding: None.

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

1. Sharma M, Bishnoi S, Martirena F, Scrivener K. Limestone calcined clay cement and concrete: a state-of-the-art review. *Cem Concr Res.* 2021; 149:106564.
2. Scrivener K, Martirena F, Bishnoi S, Maity S. Calcined clay limestone cements (LC3). *Cem Concr Res.* 2018 ;114 :49-56.

3. Dhandapani Y, Sakthivel T, Santhanam M, Gettu R, Pillai RG. Mechanical properties and durability performance of concretes with Limestone Calcined Clay Cement (LC3). *Cem Concr Res.* 2018 ;107 :136-151.
4. Direction de la Geologie, Ministere des Mines et de la Geologie du Senegal. Catalogue des ressources minerales du Senegal. Republique du Senegal ; 2023.
5. Mordor Intelligence. Calcined Clay Cement Rheology Modifiers Market - Growth Trends and Forecasts (2026-2031). Market report; 2026.
6. Swiss Agency for Development and Cooperation. LC3 - A Sustainable Alternative for the Cement Industry. Zoi Environment Network; 2022.
7. Adeniyi FI, Ogundiran MB, Hemalatha T, Bharatkumar Hanumantra B. Characterization of raw and thermally treated Nigerian kaolinite-containing clays using instrumental techniques. *SN Appl Sci.* 2020; 2:821.
8. Danner T, Norden G, Justnes H. Characterisation of calcined raw clays suitable as supplementary cementitious materials. *Appl Clay Sci.* 2018 ;162 :391-402.
9. AFNOR. NF P18-513 : Metakaolin, addition pouzzolanique pour betons - Definitions, specifications, criteres de conformite. Association Francaise de Normalisation; 2012.
10. Avet F, Snellings R, Alujas Diaz A, Ben Haha M, Scrivener K. Development of a new rapid, relevant and reliable (R3) test method to evaluate the pozzolanic reactivity of calcined kaolinitic clays. *Cem Concr Res.* 2016; 85:1-11.
11. Alujas A, Fernandez R, Quintana R, Scrivener KL, Martirena F. Pozzolanic reactivity of low grade kaolinitic clays: Influence of calcination temperature and impact of calcination products on OPC hydration. *Appl Clay Sci.* 2015; 108:94-101.
12. Fernandez R, Martirena F, Scrivener KL. The origin of the pozzolanic activity of calcined clay minerals: A comparison between kaolinite, illite and montmorillonite. *Cem Concr Res.* 2011 ;41 :113-122.
13. Arvaniti EC, Juenger MCG, Bernal SA, Duchesne J, Courard L, Leroy S, et al. Determination of particle size, surface area, and shape of supplementary cementitious materials by different techniques. *Mater Struct.* 2015; 48:3687-3701.
14. White WA. Atterberg plastic limits of clay minerals. *Am Mineral.* 1949; 34:508-512.
15. Bhavya K, Nagaraj HB. Influence of soil structure and clay mineralogy on Atterberg limits. *Sci Rep.* 2025 ;15 :15459.

How to cite this article: Cheikh Kairé Ndiaye, Dame Keindé, Seydou Khoulé Diagne, Ibra Sene. Physicochemical, mineralogical and thermal characterization of a lateritic clay from Toglou (Senegal) for potential use as a reactive clay in LC3 cements. *International Journal of Research and Review.* 2026 ; 13(10) : 280-290. DOI : <https://doi.org/10.52403/ijrr.20261026>
