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Characterization of pozzolan from Lake Tison and Study of its effect on cement properties

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Abstract: Additives in cements have become essential in cement manufacture because of their beneficial effects on the mechanical properties. They also contribute to the reduction of clinker consumption, which is advantageous for the environment. This study concerns the characterisation of pozzolans from Lake Tison for their use in cement manufacture. To achieve this, a geological exploration has been carried out in the field, followed by a physical characterisation (density, petrography, mineralogy, and geochemistry) of the collected pozzolan samples. The results showed that the density of these pozzolans is high, and they are made up of phenocrysts, microlites of olivine, clinopyroxene, plagioclase, and oxides. The sum of the three main oxides (SiO_2, Al_2O_3 and Fe_2O_3) complies with standards (> 70%), as the glass content (> 34%) and the activity index (> 67%). These characteristics indicate that the pozzolans from Lake Tison are reactive. Four blended cements were then formulated with a Portland cement substitution rate of 10, 20, 25 and 30%. The formulated pastes had a higher C-S-H and a lower portlandite content. Thermal analysis (TGA/DSC) of the cement pastes and compressive strength led to the conclusion that addition of Lake Tison pozzolan can improve long-term compressive strength and delay cement setting time. It could then be used as an additive cementing material.

1. Introduction

Cameroon is experiencing a rapid demographic growth, with a population expected to reach 30 million by 2030 (UN, 2024). This increase in population is leading to an increasing demand for housing and infrastructure, that necessitates the production large quantities of cement (Savadogo., 2017).

However, the manufacture of Portland cement is a polluting activity that contributes to greenhouse gas emissions and environmental degradation (Anissa et *al*., 2014; Emad et *al*., 2013). Indeed, cement production is responsible for about 7% of global CO_2 emissions, with one ton of CO_2

emitted per ton of Portland cement produced (IPCC, 2014; Fabiyi, 2013). Furthermore, the use of pozzolans in cement manufacture offers environmental benefits, with a reduction in greenhouse gas emissions associated with the production of traditional cement (Savadogo, 2017; Mohammed Belhadj et *al*., 2016; Mtarfi et *al*., 2016), and economic benefits, with lower production costs (Bajarea et *al*., 2013). In addition, pozzolans can improve the performance of construction materials in terms of resistance to chemical and physical aggression (Djon et *al*., 2017; Chaib et *al*., 2016; Abd-El Aziz, 2012).

To date, studies on pozzolans in Cameroon have focused mainly on the Cameroon Volcanic Line, where important deposits have been identified, such as those of Foumbot (Lemougna et *al*., 2013), Djoungo (Tchakoute et *al*., 2013; Lemougna et *al*., 2013; Yankwa et *al*., 2016), Galim (Tchakoute et *al*., 2013), and Manjo (Baenla et *al*., 2019). The material from some of these massifs is exploited by the Company CIMENCAM for the manufacture of blended Portland cement. However, the Adamawa Plateau, which covers more than 60,000 km², is still relatively unexplored in this domain. Preliminary studies revealed the presence of pozzolan deposits in the Lake Tison zone, but no more detailed studies have been carried out to characterize these deposits or assess their potential for cement manufacture.

The aim of this study is therefore to determine the physicochemical properties of pozzolan from Lake Tison and assess its potential for cement manufacture. The results of this research will contribute to the development of mineral resources for cement production in Cameroon, with a positive economic impact at the local level.

2. Materials and Experimental methods

2.1. Materials

2.1.1. Pozzolan

The pozzolan studied comes from the town of Ngaoundéré (Figure 1), which is located between latitudes 7°19.389' and 7°21.254' N and longitudes 13°33'40’ and 13°35'51’" E, at an average altitude of 900 to 1500 m (Ngounou et *al*. 2006) on the Adamaoua orographic ridge, trending N70°E, at the junction with the “Cameroon line”, trending N30°E.This pozzolan comes precisely from Lake Tison, which is located between latitudes 7°14'40'“N and 7°16'10”'N and longitudes 13°33'30'“E and 13°34'40”'E.

The pozzolan deposit (Figure 2) from Lake Tison is a mountain massif located on the western shore of the lake. The massif is 1,261m at its highest point, with a height of 176 m above the substratum (Fig. 2). It covers an area of around 50 hectares and has a volume of about 37,303,200 m^3. The pozzolan massif at Lake Tison is structured into prisms with various geometric shapes (square, rectangular, hexagonal, etc.). These prisms are generally cut horizontally into 10 cm of slate up to more than a meter thick. It is covered by a centimetric weathering patina (1.5-5 cm). When broken, the color of lava is dark grey. The fresh matrix has a honeycomb structure. As part of this study, we collected four pozzolan samples, which we named Pz$_1$, Pz$_2$, Pz$_3$, and Pz$_4$. These samples were sampled to study their properties and characteristics for potential use in cement manufacturing.

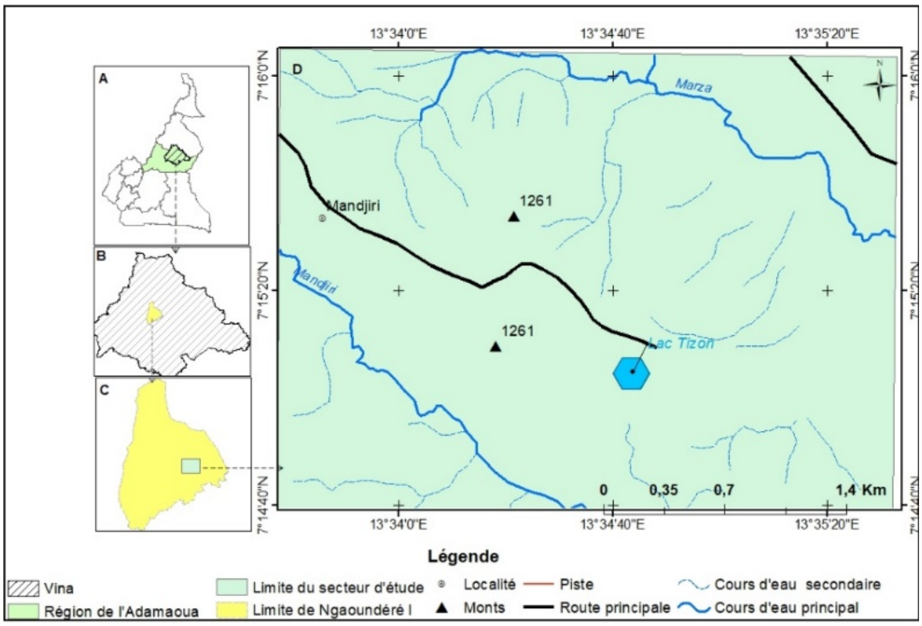

Figure 1. Location of the study area **a**: Location of Adamawa region in Cameroon. **b**: Location of Department of Vina. **c**: Location Sub division of Ngaoundere 1^{e}. **d**: Map of the study area.

Figure 2. **a**: Pozzolan of Lake Tison. **b**: Panoramic view of the Lake Tison volcano.

2.1.2. Portland Cement

The cement used in this study is a white Portland cement - CEM I 42.5 R (Hamadache et *al.* 2016) manufactured by CIMENCAM. Its trade name is SUBLIM. It has an apparent density of 3.06 g/cm^{3} and a Blaine specific surface of 4,700 cm²/g. Its loss on ignition is 0.76, its water demand is 28.33% and its setting time is 130 minutes. This cement is formulated with 96% clinker (Lafarge Ciment d'Oggaz clinker) and 4%, gypsum, a secondary constituent which is used to regulate the setting of the cement. Its composition of is given in Table 1.

2.2. Experimental methods

Fieldtrips were carried out: firstly, a general lay of the land was conducted, and the massif used as geological material was identified. Secondly, samples were taken from the summit, mid-slope, and base to obtain a representative sampling of lavas.

Table 1. Mineralogical and chemical composition of Cement.

Mineralogical composition (%)	
C_3S	53.30
C_2S	29.43
C_3A	10.48
C_4AF	0.69
Chemical composition (%)	
SO_3	2.43
Cl^-	0.02
Insolubles	-
MgO	2.75
Equivalent Alkali (Na_2O + 0,658 K_2O)	0.40

2.2.1. Preparation of pozzolan

The pozzolan was prepared following four steps: (1) Drying, to remove moisture from the materials and facilitate the grinding process. (2) Grinding, which consists in fragmenting the pozzolan to obtain smaller grain sizes. This unitary operation increases the specific surface area of the materials and, therefore, their reactivity. We used a ball mill from the Applied Inorganic Chemistry Laboratory at the University of Yaounde 1 (Figure 3a). (3) Sieving: we used sieves to obtain grain sizes of 80 µm or less (Figure 3b). (4) Weighing: we used a Precisa balance with a precision of 0.1g.

Figure 2. **a**: The ball mill. **b**: Sieves with different mesh sizes (500, 250 et 80 µm).

2.2.2. Formulation of compound cements

To prepare the compound cement, various ingredients including Portland cement and Pozzolan powder were carefully mixed at a substitution rate of 10%, 20%, 25% and 30%. The weight compositions as a function of the Portland cement content and of the clinker content are given in Tables 2 and Table 3 respectively.

Table 2. Weight compositions of different cements according to Portland cement.

	Pouzzolane (%)	Ciment portland CEM I 42.5R (%)
CIM$_0$	0	100
CIM$_{10}$	10	90
CIM$_{20}$	80	20
CIM$_{25}$	25	75
CIM$_{30}$	30	70

2.2.3. Making of test bodies

In this study, experiments were conducted on cement pastes. Using pastes made from Portland cement and pozzolan, it is possible to study in detail the interactions within the cement matrix. Three different formulations were studied for this test body. A control formulation based on Portland cement and two formulations prepared with partial mass substitution of Portland cement by pozzolan powder from Lake Tison.

Table 3. Weight compositions of different cements according to clinker.

	Pozzolan (%)	Clinker (%)	Gypsum (%)
CIM$_0$	0	96	4
CIM$_{10}$	10	86,4	3,6
CIM$_{20}$	20	76,72	3,28
CIM$_{25}$	25	72	3
CIM$_{30}$	30	67,2	2,8

The substitution rate studied was 25%, as recommended by American standard ASTM C 618 (2003). For the mass ratio of the formulation, we consider the mass of the binder (CIM) which is equal to the sum of masses of Portland cement (CIM$_0$) and pozzolan (P):

$$\mathbf{CIMx = CIM0 + P} \qquad \textbf{Eqn. 1}$$

Where CIM$_X$: mass of the blended cement prepared
CIM$_0$: mass of the Portland cement
P: mass of the pozzolan

About pastes, the ratio W/C = 0.5 with W the volume of water (ml) and C the mass of cement (g). This ratio is used to obtain a paste with a normal consistency.

To mix the pastes, the cement is poured into the water in a beaker and this was stirred immediately for three minutes. The obtained cement pastes were stored at 20 °C in plastic bags (Figure 5a). The composition of the different cement pastes is shown in Table 4. After 28 days, these pastes, now transformed into cement blocks, were ground into powder for thermal analysis (Figure 5b). Usually, the activity index is used to evaluate the contribution of a pozzolan in a bended cementitious with a rate of 25%. In this work, this concept has been extended by applying it to different substitution rates in order to determine an optimum pozzolan valorization content. Experiments first consisted in producing blended cements in which various percentages (10%, 20%, 25% and 30%) of cement were replaced by identical mass contents of pozzolan. These cements have been used to manufacture normal mortars marked M_{10}, M_{20}, M_{25} and M_{30}. The reference mortar, which does not contain pozzolan, is labelled M_0.

Figure 5. a: Packaging of cement pastes. **b**: Cement powder for thermal analysis.

Table 4. Composition of Cement paste.

N° Paste	Portland cement (g)	Pozzolan (g)	Water (ml)	W/C
Paste $_1$	20	0	10	0,5
Paste $_2$	15	5	10	0,5
Paste $_3$	15	0	10	0,5

The composition of the mortar to be tested is as follows: Sand (S): 1350 ± 5 g; Cement (C): 450 ± 2 g; Distilled water (W): 225 ± 1 g.

The resulting mortar was placed into test tubes in two layers. The test tubes were then covered with plastic film to prevent water evaporation and stored at 20°C. Twenty-four hours later, they were removed from the mould and stored in water, to prevent the dissolution of portlandite, until the day of testing, twenty-eight days later. The composition of the different mortar formulations is given in Table 5.

Table 5. Composition of mortars. (Berredjem et *al*., 2016 , Bouamrane et *al*., 2014)

	Pozzolan (%)	Cement (g)	Water (ml)	Sand (g)	W/C	S/C
M_0	0	450	225	1350	0,5	3
M_{10}	10	450	225	1350	0,5	3
M_{20}	20	450	225	1350	0,5	3
M_{25}	25	450	225	1350	0,5	3
M_{30}	30	450	225	1350	0,5	3

2.2.3. Analysis methodology

We carried out many analyses on the pozzolan samples from Lake Tison in order to determine their physical and chemical properties. The methods used are described below:

- Density measurement: it was measured using a Micromeritics AccuPyc 1330 gas pycnometer. The samples were ground to a fine powder and then placed in the pycnometer.
- Polarizing microscope observations: these were carried out using an Olympus BX51 optical microscope. The samples were prepared in thin slides and observed under different lighting conditions.
- Mineralogical analysis (DRX): for this, we used a Bruker D8 Advance X-ray diffractometer. The samples were ground to a fine powder and placed on a glass slide. Measurements were taken in a range of 2θ between 5° and 80°, with a step of 0.02° and an acquisition time of 1 second per step.
- Geochemical analysis: a Thermo Scientific iCAP 6500 inductively coupled plasma atomic emission spectroscopy (ICP-AES) where used. Samples were digested in a mixture of strong acids (HNO_3, HF, HCl) before analysis.
- Thermal analysis (TGA/DSC): there was carried out using a TA Instruments SDT Q600 thermal analyser. The samples were heated at temperatures increasing from 20°C to 1000°C, with a heat rate of 10°C/min.
- Compressive tests: we used an Instron 3382 test press. The samples were prepared into a cylinder shape and subjected to an increasing load until fracture.

Calculation of the strength activity index (SAI): it is used to test the pozzolanic activity of the material, taking into account the compressive strength at 28 days of hardening of 25% of the material to be tested (Jabri *et al.,* 2013; Lamrani et *al*., 2014). The material is considered pozzolanic when the SAI is equal to or exceeds 0.65 after 7 and 28 days of hardening of the cement:

$$\mathrm{SIA} = \frac{\mathrm{A}}{\mathrm{B}}\mathrm{x}100 \qquad \mathrm{Eqn.\,2}$$

Where A is the compressive strength of the mortar made with cement containing additives (MPa)
B is the compressive strength of the control mortar (cement without additives) (MPa).

3. Results

3.1. Density

The values for density of pozzolans from Lake Tison are very homogeneous, with a slight variation of 0.06 g/cm³ (see Table 6). This suggests that the pozzolans have a very similar mineralogical composition, suggesting that they come from the same geological source. The average density of the samples is 1.05 g/cm³, which is typical for pozzolans. This value indicates that the pozzolans from Lake Tison have a relatively high density, indicating that they can be used as a construction material for applications where mechanical strength is important.

Table 6. Density of pozzolan samples of du Lake Tison.

Samples	**Density (g/cm^3)**
Pz_1	1.02
Pz_2	1.02
Pz_3	1.04
Pz_4	1.05

The results on high density and homogeneous mineralogical composition of pozzolans from Lake Tison have important implications for cement manufacture: they can be used as a substitute material for traditional cements. The stability of their physical properties ensures a consistent quality of the produced cement.

3.2. Petrographic characteristics

Photographs of samples showed fairly large crystals of olivine, plagioclase and clinopyroxene and oxide (Figure 6). For macroporous pozzolan, olivine crystals observed are strongly cracked subautomorphs. They are less abundant, about 15% of the volume of the rock, and contain rare oxide inclusions. The largest can reach 2 to 3 mm. As for the plagioclase crystals, they are automorphic and may represent 5 to 10% of the volume of the rock. They sometimes include small oxide crystals and are often in contact with olivine crystals as well as plagioclase and clinopyroxene microlites. The visible brown clinopyroxene crystals are xenomorphic and very small, less than 1mm. They are less abundant in the rock than olivine crystals.

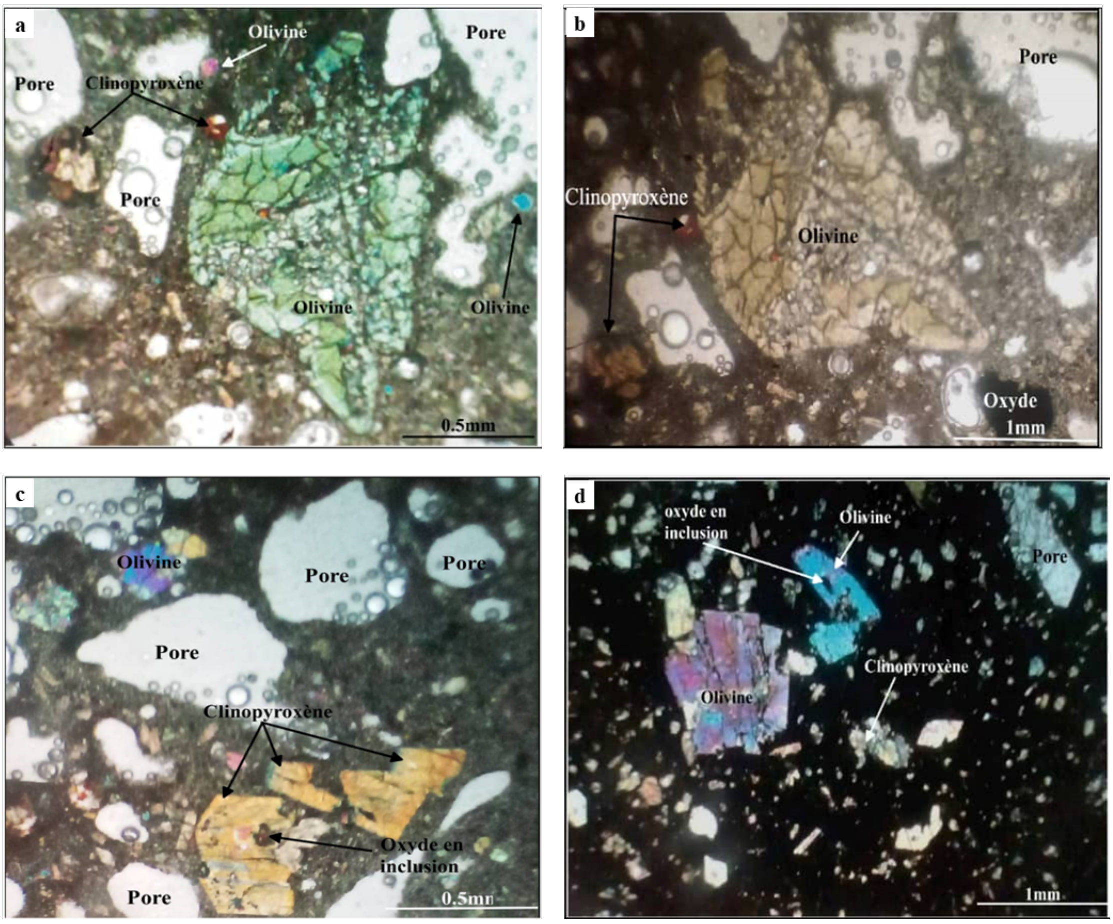

Figure 6. Petrographic composition of pozzolan samples.
a and **b**: macroporous pozzolan. **c** and **d**: macroporous pozzolan.

Pyroxene crystals are rarely and have a black oxide crown. Oxide crystals are rare in the rock (2% in volume). They are sub-rounded and xenomorphic in the matrix. All these crystals have a porphyritic microlitic texture. Concerning microporous pozzolan, olivine crystals are also the least abundant in the rock. They are automorphic to sub-automorphic. Plagioclase crystals are present in the form of microlites. They are automorphic and represent 35% of the volume of the rock. They represent most of the matrix and are highly crystalline. Here, clear clinoyroxene crystals are less abundant than plagioclase crystals (about 5 to 10% by volume of the rock). They are xantomorphic and very small (0.2 to 0.5 mm). Oxide crystals are rare in the rock (2% by volume). They are sub-rounded and xenomorphic in the matrix.

3.3. Mineralogical analysis (XRD)

Pozzolan patterns (Figure 7) showed that the pozzolans are composed of common minerals in volcanic material, mainly augite, forsterite, labradorite, and magnetite. Their presence suggests that this rock is the result of a magmatic process that took place in an area of active volcanism. Augite and forsterite are common minerals in volcanic rocks. Labradorite is a plagioclase mineral that can form under conditions of high temperature and pressure while magnetite is a ferromagnetic mineral that can form under reducing conditions. No hydraulic minerals were recognized in this material, but the detachment of the base line of the diffractograms between 2θ equal to 20° and 2θ equal to 73° suggests the presence of a vitreous phase due to the presence of volcanic glasses. The glassy phase in pozzolan is characteristic of volcanic rocks that rapidly cooled, preventing complete crystallization of the minerals. This glassy phase may be composed of amorphous silicates, metal oxides, and other elements, and has an essential influence on the properties of pozzolans, on the cement's reactivity with water, and on its durability.

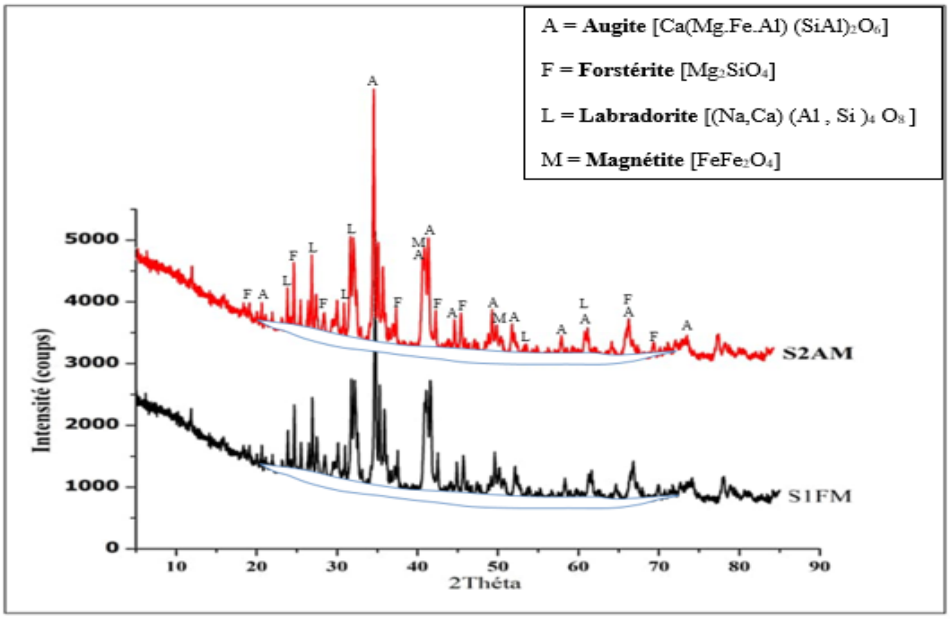

Figure 7. XRD Patterns of pozzolan samples.

3.4. Geochemistry

3.4.1. Chemical composition

Geochemical characteristics of the samples from Lake Tison are given in Table 7. They indicate that the pozzolans from are made of silica, alumina and iron oxide as main elements. Calcium oxide, magnesium oxide, sodium oxide, potassium oxide and titanium oxide are the minor elements. The proportions of these main elements and the minor elements correspond perfectly to the limits defined by the French standard NF P18 308 (1965) for pozzolans.

3.4.2. Reactivity and activity index

According to ASTM C 618 (2003) a material is considered as pozzolan if:

- its chemical composition verifies: $SiO_2 + Al_2O_3 + Fe_2O_3 > 70\%$;
- Its glass content given by the difference between the crude silica and lime contents is greater than 34%. (SiO_2 - $CaO > 34\%$);
- Its activity index for a substitution rate of 25% I_{25} at 28 days is greater than 67%.

Considering the chemical composition of the Lake Tison pozzolan, this sum is respectively equal to 71.80%; 70.30%; 71.43 and 72.25% (Figure 8), for the four pozzolan samples. These values are less than those from other parts of Cameroon (75.50 for Tombel, 74.25 for Foumbot and 72.10 for Djoungo). It is due to the difference of chemical composition of materials. Globally, this means they can be used as pozzolanic materials; that is, they can partially substitute clinker.

Table 7. Geochemical characteristics of pozzolans.

Oxides	Pz_1	Pz_2	Pz_3	Pz_4
SiO_2	45.5	45	45.1	45.62
TiO_2	2.81	2.48	2.61	2.8
Al_2O_3	13.8	13.45	13.8	14.5
Cr_2O_3	0.043	0.042	0.04	0.04
Fe_2O_3	12.5	11.85	12.53	12.25
MgO	0.19	0.19	0.18	0.19
MnO	8.4	8.45	9.09	8.42
CaO	9.9	9.83	10.1	9.07
Na_2O	3.92	4.4	4.04	3.77
K_2O	2.35	2.15	1.84	1.73
P_2O_5	0.76	0.76	0.68	0.62
BaO	0.08	0.08	0.08	0.02
SrO	0.13	0.13	0.13	0.13
LOI	0.63	-0.05	-0.33	0.34
Total	100.36	98.76	99.89	99.6

The quality of a pozzolan depends on its glass content. To determine this, we calculate the difference between the content of silica and lime (SiO_2 - CaO). When this difference is less than a threshold value of 34%, the pozzolans do not contain a glassy phase. According to the given centesimal chemical compositions, this difference is respectively equal to 35.6%; 35.17; 35 and 36.55% (Figure 8). This means that the pozzolans studied contain a glassy phase, and can therefore bind the calcium hydroxide released by the cement. Figure 9 shows the calculated activity indices as a function of the pozzolan substitution rate in the cement. The maximum index of 88% was obtained for a substitution rate of 10%. For the standard ASTM C 618 composition corresponding to a substitution rate of 25%, the activity index calculated is 78%. It is therefore higher than the value of 67% required to validate the pozzolanic nature of this material. On the other hand, given that ASTM C 618 requires cement made from pozzolanic material to have a minimum activity index of 75%, we can deduce that pozzolan can be used up to 30%. However, in the rest of the study, we will work with three (03) substitution percentages 10%, 20% and 30%.

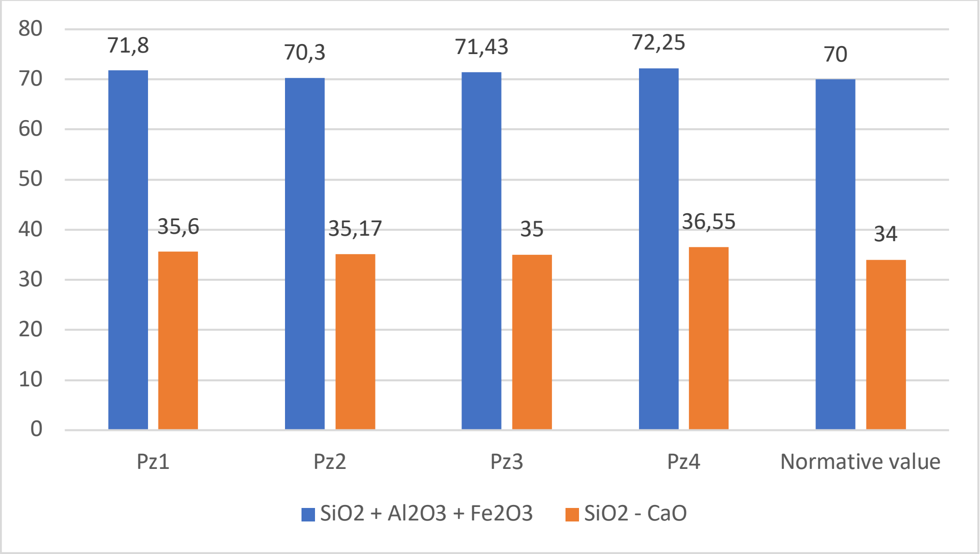

Figure 8. Reactivity of pozzolans from Lake Tison.

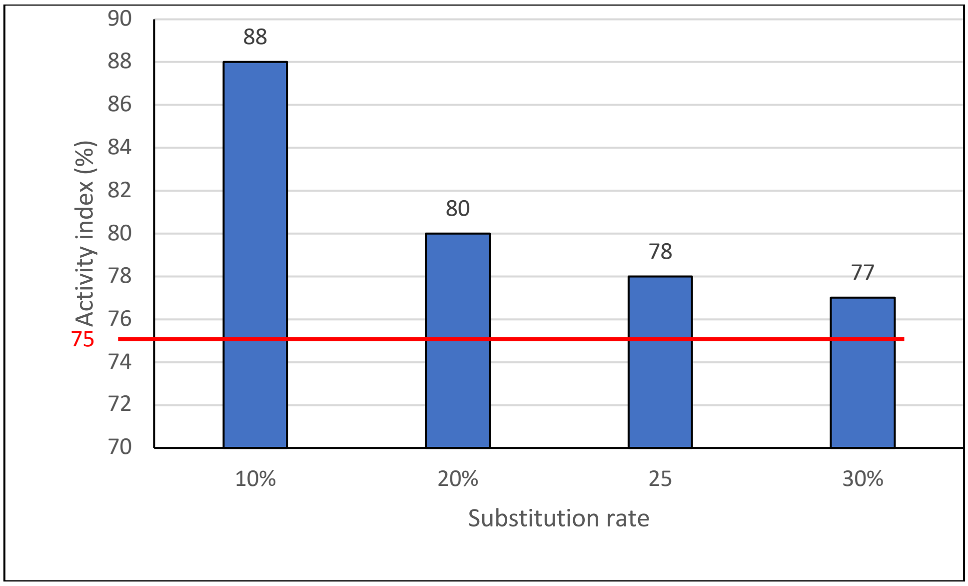

Figure 9. Evolution of the activity index at 28 days with the substitution rate and normative limit of 75%.

3.5. Thermal analysis TGA/DSC

The TGA-DSC thermal curves (Fig. 7) show that a significant mass loss is observed between 100 and 200°C in TGA (14.20%), with a prominent endothermic peak in DSC. This indicates the dehydration of the C-S-H formed by the reaction between portlandite and the silica in the pozzolan. This considerable mass loss is accompanied by a slight mass increase between 400 and 500°C (2.84%) and a small endothermic peak in DSC, corresponding to the dehydration range of portlandite. This indicates the low presence of portlandite [$Ca(OH)_2$]. There is also a loss of mass between 630°C and 830°C (1.84%) and a weak endothermic peak in DSC corresponding to the decarbonation of calcite.

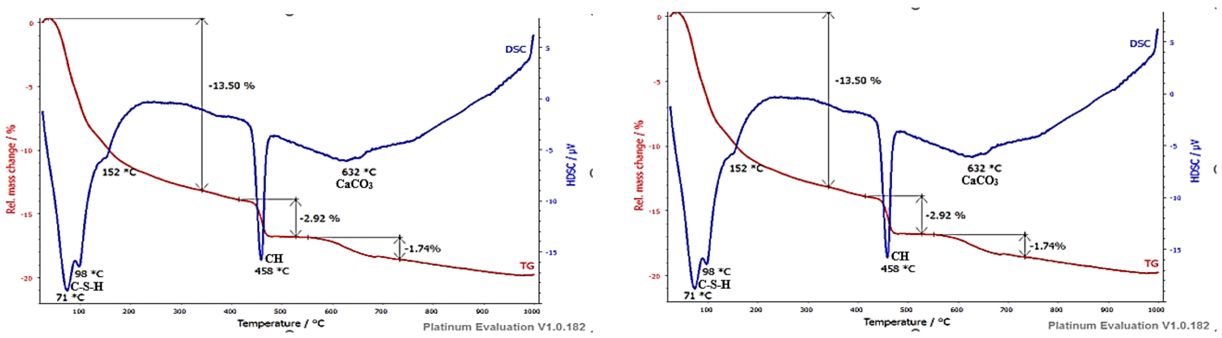

Figure 7. TGA and DSC thermograms of Portland cement and pozzolanic cement paste.

Given that pozzolanic reaction consumes portlandite, the commonly used chemical method to assess pozzolanicity of a material is to determine the amount of formed CSH and portlandite fixed, as stated in the French standard (NF EN 196-5, 2013). The levels of CSH and residual Portlandite are indicated by the mass loss observed on the TGA/DSC thermograms (Figure 7). When we compare the results of the compound cement pastes prepared with those of the control Portland cement paste, we find that, as expected, the compound cement pastes have a higher C-S-H content and a lower Portlandite content. This means that a large quantity of Portlandite was transformed into CSH gels by the pozzolanic reaction between the calcium hydroxide and the silica of the pozzolans in the blended pastes: The Lake Tison pozzolan in the form of an excellent powder and in the presence of moisture reacted chemically with the calcium hydroxide to form CSH, which is the resistant and impermeable part of the cementitious matrix. This improves the mechanical strength of the cement. This increase in CSH and decrease in portlandite confirms that the Lake Tison pozzolan is reactive.

3.6. Compressive tests

For each formula, a curve has been plotted, that follows the evolution of the average compressive strength as a function of age (Figure 8). The results show that the compressive strength of mortars decreases with increasing pozzolan content, due to the low chemical reactivity of pozzolan with water. This suggests that pozzolans can reduce the mechanical strength of mortars. However, it is essential to note that the compressive strength increases over time for all pozzolan levels. This indicates that mortars continue to gain strength over time, because of the hydration reaction of the cement. The optimum pozzolan content for mortars could be between 10% and 20%, as this achieves high compressive strength while reducing costs. These results have significant implications for cement manufacture. Pozzolan can be used as a substitute for traditional cements, but it is essential to control its content to avoid excessive reductions in mechanical strength. Pozzolan-based mortars can be used for applications where mechanical strength is not crucial, such as repair work or light building.

4. Discussion

The results presented above demonstrate that pozzolan from Lake Tison has interesting mineralogical, geochemical and physical characteristics for use as a raw material in cement manufacture. The geochemical composition of the pozzolan, with an average SiO_2, Al_2O_3, Fe_2O_3 and CaO content of 45.5%; 13.8%; 12.5% and 9.9% respectively, satisfies ASTM C618 standards for pozzolanic cements. The average sum (SiO_2 + Al_2O_3 + Fe_2O_3) is 71.45%, which is above the minimum required limit. This geochemical composition is similar to that of the St Thibéry volcanic pozzolans in France (Segui, 2011), which reported SiO_2, Al_2O_3, and Fe_2O_3 contents of 44.2%, 13.2% and 10.5%, respectively. By comparing the chemical compositions of pozzolans from the Tombel plain (Tchoua., 1971; Bidjocka et *al*., 1993; Wandji., 1995), Foumbot (Lemougna et *al*., 2014), Djoungo (Lemougna et *al*, 2014), St Thibéry in France (Segui, 2011) and Lake Tison and Lake Tison (Adamaoua Plateau), the average sum of the main oxides (SiO_2 + Al_2O_3 + Fe_2O_3) in these different pozzolans is similar (higher than the normative value of 70%). The difference in glass content between of these different pozzolans is also similar, i.e., higher than the normative value of 34% (Figure 9).

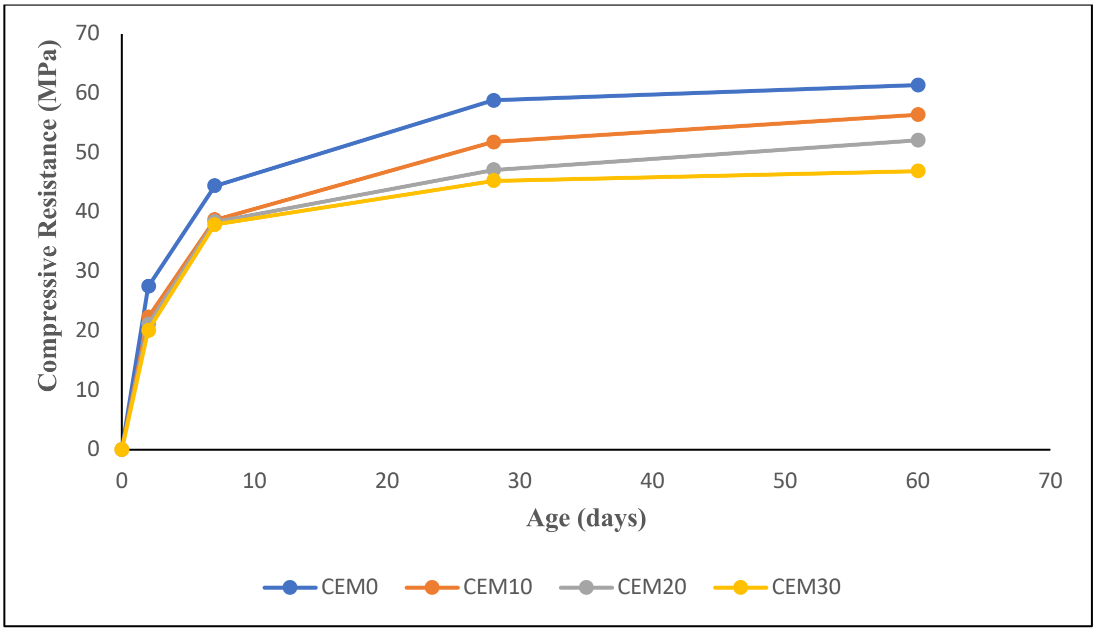

Figure 3. Morar compressive resistance as function of time.

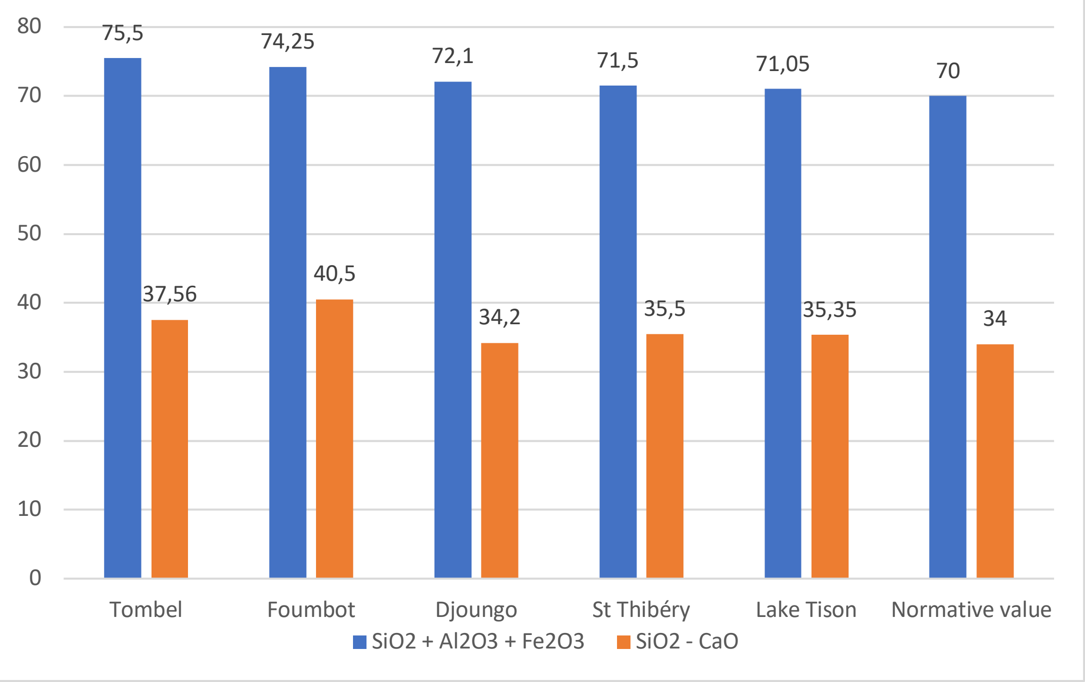

Figure 4. Reactivity of pozzolans from lake Tison and others regions.

X-ray diffraction (XRD) results revealed the presence of minerals such as augite, forsterite, labradorite, and magnetite, as well as volcanic glasses. The presence of these volcanic glasses is characteristic of volcanic pozzolans and contributes to their pozollanic activity.

The results of the compressive strength tests show that the pozzolan from Lake Tison has satisfactory compressive strength, ranging from 22.3 to 54.8 MPa. These results are comparable to those obtained with other pozzolans reported in literature. For example, the pozzolan from Béni Saf in Algeria has a similar compressive strength (Logbi, 2019; Benkaddour et *al*., 2009; Kerbouche et *al*., 2009; Ghrici et *al*., 2006). Globally, the results of this study show that the pozzolan from Lake Tison complies with the requirements of American standard (ASTM C618, 2003) for pozzolanic cements, as well as the requirements of European standard (NF EN 197-1, 2012) for cements. The Lake Tison pozzolan, as well as the Tombel, Foumbot and Djoungo pozzolans (already used by cement manufacturers), has the potential to be used by cement companies as an additive to clinker for blended cements.

Conclusion

This study assessed the geochemical, mineralogical, and physical properties of the pozzolan from Lake Tison, for its use as a raw material in cement manufacture. The results showed that this pozzolan has good characteristics, with geochemical composition that satisfies standards requirements of ASTM C618. Its mineralogical composition revealed the presence of volcanic glass, which contributes to the pozollanic activity of the pozzolan, a high density, and a satisfactory compressive strength. This suggests it could be used as a partial or total substitute for Portland cement in construction applications, helping reduce CO_2 emissions and improve the durability of structures. This study demonstrates the potential of Lake Tison pozzolan as a raw material for cement manufacture and offers interesting perspectives for its exploitation.

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