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Characterization of Diatomite for Its use in Construction: Case Diatomite Sampled in Northern Chad

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Abstract*: *The need for energy for the purpose of thermal comfort in buildings is constantly growing. To minimize this need, we can improve the performance of the building envelope, which is the seat of several thermal stresses, which encourages us to develop, apart from renewable or alternative energies, construction materials for buildings capable of storing energy. For this, the integration of innovative passive materials in the building envelope makes it possible to reduce energy consumption and ensure thermal comfort in countries with a very hot climate such as the desert zone of Chad. We were thus interested in the characterization of diatomite which is used to build a good majority of dwellings in the Lake Chad, Kanem and BET regions. To this end, samples of diatomite used in the construction were taken from Faya, the capital of the far north of Chad, on which we carried out mineralogical analyzes as well as thermal and mechanical characterization. Observations at the SEM, analyzes by fluorescence of rays X and Diffractograms clearly confirm pure diatomite. Furthermore, the results of the various thermo-physical and mechanical tests presented a material which has a low mechanical resistance but a good thermal resistance. Therefore, the diatomite which has been the subject of this study has no negative effect on the environment, it is an excellent thermal insulation material capable of storing thermal energy in buildings.

Keywords:* *Diatomite, Mineralogical Analysis, Thermal Resistance, Mechanical Resistance, Thermal Storage.

I. INTRODUCTION

Energy consumption to ensure thermal comfort in buildings continues to increase in Chad and in the countries of the sub-region despite low energy coverage. Most of the country's electricity production is of very polluting and drying up fossil origin. The development of new ecological materials capable of conserving energy is a solution for the reduction of excessive energy consumption. Much of the research work is oriented towards passive biosource materials. Today synthetic materials such as cement have considerable disadvantages on the environment and a cost beyond the reach of the population. Much of northern Chad has relatively abundant geological resources of diatomite, the mechanical characteristics of which are improved by mixing them with straw or animal waste [1]. Due to its porous structure, diatomite has a low density and a very low operating cost [2][11]. In the distant past, diatomite was used as a mineral additive in the manufacture of pottery and light bricks [3] [13]. Diatomite is one of the most widely used local building materials in northern Chad. It is with this in mind that we have taken diatomaceous soil in the locality of the city of Faya-Largeau for studies of its mineralogical, mechanical and thermo-physical characteristics. The objective of this work is to analyze pure diatomite and then to determine the thermal and mechanical characteristics of diatomite in order to optimize its use as thermal insulation materials in buildings.

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II. MATERIAL USED: DIATOMITE

Diatomites are biochemical sedimentary rocks, which are part of the family of opals (amorphous silica), with very high porosity, soft although rough to the touch. They are formed by the accumulation of frustules of unicellular algae (diatoms) which ensure the return to the solid state of silicon [1]. Diatomite is a natural material found in several uses after treatment and calcination. It is used as a filtration agent for water, food sugars, oils, table fats and other chemical products. The use of diatomite's versatility is widespread in certain applications such as paint, dental construction, brick insulation and concrete waterproofing through its fineness and pozzolanic effect [3] [13]. Processors will find a multifunctional mineral additive that includes: Anti-blocking, shine, cost control, density control, high surface area, reinforcement, controlled absorption, precise abrasive properties [4]. In the chemical industry, diatomites are used as a raw material for obtaining liquid glass. The high polydispersity and porosity of diatom particles promote interaction with sodium oxide or hydroxide. They are used for the destruction of insects in yards and plantations. Due to its light weight, porosity and chemical neutrality, it is used in many applications such as liquid filtration, cement production, paint, plastics and in small percentage in pharmaceuticals.

In the Bodélé depression, diatomites from ancient lacustrine phases are the source of major dust storms [5].

Fig. 1. Diatomite quarry

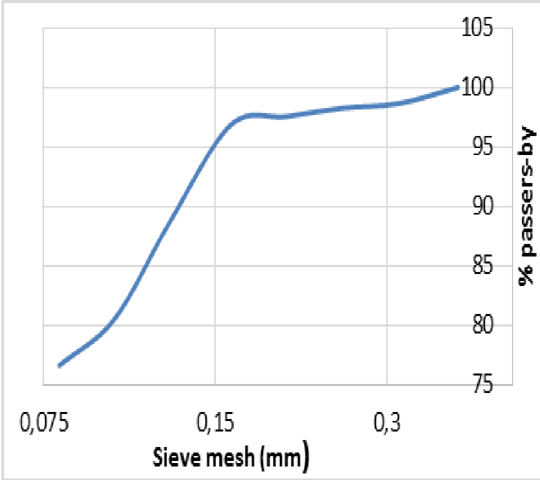

Fig. 2. Particle size analysis curve

III. GEOTECHNICAL ANALYSIS

Geotechnical tests are carried out for the physical characterization of the diatomite thus serving for its identification. For this purpose, the natural water content is determined from the standard [6]. The specific weight is obtained using the water pycnometer according to the standard [7]. The void index and the porosity are deduced from the relationships that exist between the different physical parameters.

A. Physical property test results

The values of the physical properties of diatomite grouped in Tables 1 and 2 show that the apparent and real densities are very low and also the porosity is too high compared to most building materials [6, 7] .

Table- I: Geotechnical characteristics of diatomite [NF P 94-050, NF P 94-054]

Test	symbols	units	values
Apparent density	ρd	kg.m^{-3}	416
Actual density	ρs	kg.m^{-3}	685
Natural water content	W	%	8.7
null index	E	%	4.83
porosity	N	%	85

B. Particle size analysis

The particle size test by sieving showed us that diatomite is a very fine material. More than 76% passes through the 80 micron sieve. The important properties of diatomites are related to their physical structure which forms an aggregate of fine perforated particles in a regular pattern of small pores. Due to this porosity which gives it a high permeability [Vasconcelos et al; 2000], [8]. The values found in this experimental work are in the same order of magnitude as those obtained by Abakar ALI in his thesis [9].

IV. MINERALOGICAL ANALYSIS:

The samples taken are rocks of low density, presenting a certain powdery aspect. They do not react with dilute hydrochloric acid, thus excluding carbonate rocks of the "travertine" type. We focused on more or less pure diatomites.

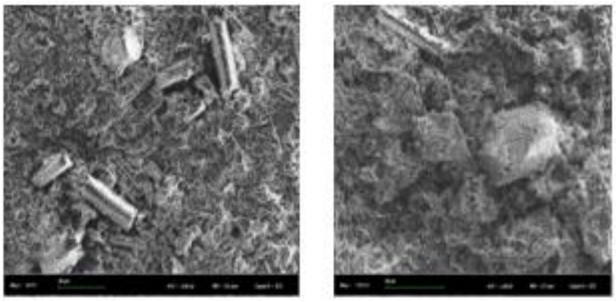

Fig. 3. Views of Sample (SEM)

SEM (Scanning Electron Microscope) observation (secondary electrons) very clearly confirms this track and clearly shows a multitude of diatom tests (essentially cylindrical shape) as well as their fragments. Analyzes by X-ray Fluorescence (FRX), expressed in masses of oxides, logically indicate the predominance of silica which corresponds to the very nature of the tests for diatoms but which also comes from the presence of Quartz and clays, detected in X-ray diffraction (XRD). The diatom test consists of an amorphous silica which does not diffract and could on the contrary correspond to the bulging of the base line of the 3 XRD images that can be seen between the angles 2θ = 15° to 30° (anticathode at copper λ = 1.54060 Angstrom). The sample contains significantly more quartz, which is detected by a significantly higher intensity of the quartz lines in XRD but which also results in a higher silica content (83%).

Table- II: Geotechnical Characteristics of Diatomite [NF P 94-050, NF P 94-054 Composition of the Faya diatomite Sample

PAF	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	CrO_3	Fe_2O_3	ZnO	SrO	Mn_2O_3
7.59	0.11	0.30	5.53	83.17	0.02	0.17	0.51	2.06	0.27	0.01	1.60	0.006	0.006	0.01

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The sample has 5.5% alumina and a PAF reduced by half. Finally in XRF, we note the presence of potassium, a little calcium and magnesium in small quantities. Calcium, however, is not associated with carbonates.

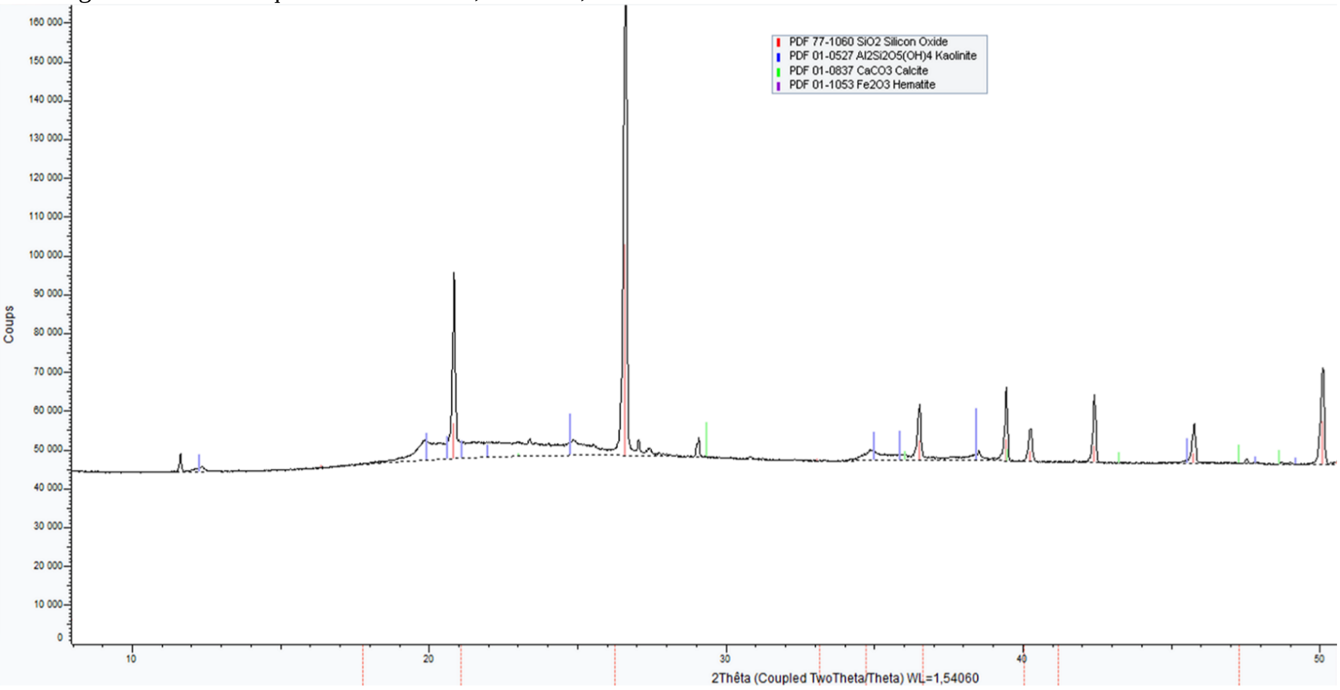

Fig. 4. Diffractograms of the Diatomite Sample

The X-ray diffraction spectrum shows that the raw diatomite consists of an amorphous mass of silica as the base carbonate mineral with some clay minerals. These results are similar to the work done by El Attmani and al [3] [13].

V. MECHANICAL CHARACTERIZATION

The measurements of the mechanical resistances are carried out thanks to the hydraulic press to determine the resistance in traction and in compression...

Fig. 5. Device for tensile test

Fig. 6. Device for compression test

The results obtained are presented in the table below.

Table- III Results of mechanical tests

ρ(kg/m^3)	R_t (MPa)	R_c (MPa)	W%
685	0,011	2,21	88

The average of the results of the mechanical resistances obtained are low compared to a material which must be used as a load carrier. at least it can be used as wall filling material

VI. THERMAL CHARACTERIZATION

Using the box method, we performed the tests on 0.27*0.27*0.04 mm3 samples to determine the thermal resistance.

Fig. 7. Picture of samples of diatomite bricks

The thermal characterization consists in determining by the box method the conductivity and the thermal diffusivity. The measurement of the thermal characteristics of materials is of great importance for materials used in buildings [2] [12]. The characteristics necessary for the evaluation of the heat balances are the thermal conductivity λ and the thermal diffusivity a.

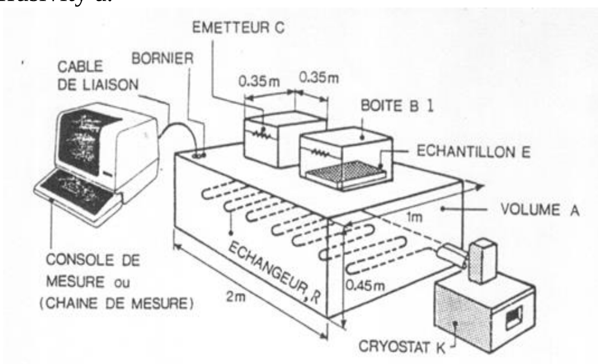

Fig. 8. Experimental apparatus

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The results obtained are shown in Table 5.

TABLE- IV: Test Results for Thermal Conductivity

e (m)	s (m2)	U (V)	R (OHM)	Q (W)	C (W/°C)	λmoy (W/m.K)
0.04	0.0729	48	1600	1.44	0.16	0.117

The thermal resistance R is given by the following formula:

$$R = \frac{e}{\lambda} \quad (1)$$

the thermal diffusivity is expressed by :

$$a = \frac{\lambda}{\rho c_p} \quad (2)$$

Thermal effusivity E describes how quickly a material absorbs or gives up heat. Since the method of the boxes that we used makes it possible to determine the conductivity and the thermal diffusivity therefore, the thermal effusivity is also deduced by the following relation:

$$E = \sqrt{\lambda . \rho . c_p} \quad (3)$$

The results obtained are close to those of FRAINE Youssouf who determined the heat capacity Cp equal to 1436 *J/Kg K* [10].

Table- V: Values of Thermal Parameters for a wall 20 cm thick

λ (W/m.K)	R (m^2.K /W)	a (m/s)	E ($W.m^{-2}.K^{-1}.s^{1/2}$)	C_p (*J/Kg K*)
0.117	1.7	$1.18\ 10^{-7}$	339.2	1436

VII. CONCLUSION

This study made it possible to determine the various characteristics of the diatomite used for a long time like material in the constructions of the traditional houses. The mineralogical analysis confirms the different constituents and presents that the samples taken as pure diatomite. Mechanical tests show that diatomite specimens have low mechanical strength but that this material can be used for partitioning or filling walls in large structures. The results of the thermal tests show that the diatomite taken from the Faya site has good thermal properties, therefore its use will save thermal energy thanks to its thermal insulation character.

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