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



Abdallah DADI Mahamat, Abakar ALI, Jean-Michel Mechling, André DONNOT, Salif GAYE

Abstract: The need for energy for thermal comfort in buildings is constantly growing. To minimise this need, we can improve the performance of the building envelope, which is the site of several thermal stresses, encouraging 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 enables the reduction of energy consumption. It ensures thermal comfort in countries with extremely hot climates, such as the desert zone of Chad. We were thus interested in characterising diatomite, which is used to build a significant 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 Chad's far north, on which we carried out mineralogical analyses as well as thermal and mechanical characterisations. Observations at the SEM, analyses by X-ray fluorescence, and Diffractograms confirm the presence of pure diatomite. Furthermore, the results of the various thermo-physical and mechanical tests presented a material that has low mechanical resistance but good thermal resistance. Therefore, the diatomite, which is the subject of this study, has no adverse environmental impact; 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

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m nergy}$ consumption to ensure thermal comfort in buildings continues to increase in Chad and the countries of the sub-region despite low energy coverage. Most of the country's electricity production is from very polluting and dwindling fossil sources. The development of new ecological

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materials capable of conserving energy is a promising solution for reducing excessive energy consumption. Much of the research work is oriented towards passive biosource materials. Today, synthetic materials such as cement have considerable environmental disadvantages and a cost that is beyond the reach of many populations. 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]. In the distant past, diatomite was used as a mineral additive in the manufacture of pottery and light bricks [3]. 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 analyse pure diatomite and then determine its thermal and mechanical characteristics to optimise its use as a thermal insulation material in buildings.

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 with various 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 specific applications such as paint, dental construction, brick insulation and concrete waterproofing through its fineness and pozzolanic effect [3]. 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, diatomite is used as a raw material for producing 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 various applications, including liquid filtration, cement production, paint, plastics, and in small percentages in pharmaceuticals.

In the Bodélé depression, diatomites from ancient lacustrine

phases are the source of major dust storms [5].

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Fig. 1. Diatomite quarry

III. GEOTECHNICAL ANALYSIS

Geotechnical tests are carried out to physically characterise the diatomite, thereby serving as a means of 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 P94-050, 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	Е	%	4.83
porosity	Ν	%	85

B. Particle size analysis

The particle size test by sieving showed us that diatomite is an excellent material. More than 76% pass through the 80 micron sieve. The essential 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].



Fig. 2. Particle size analysis curve

IV. MINERALOGICAL ANALYSIS:

The samples taken are rocks of low density, presenting a specific powdery aspect. They do not react with dilute hydrochloric acid, thus excluding carbonate rocks of the "travertine" type. We focused on diatomites that were, for the most part, pure.



Fig. 3. Views of the 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. Analyses by X-ray Fluorescence (XRF), expressed in masses of oxides, logically indicate the predominance of silica, which corresponds to the very nature of the tests for diatoms but also results from the presence of Quartz and clays, detected by 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 baseline of the 3 XRD images that can be seen between the angles $2\theta = 15^{\circ}$ to 30° (anticathode at copper $\lambda = 1.54060$ Angstrom). The sample contains significantly more quartz, as indicated by a significantly higher intensity of the quartz lines in XRD, 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 ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	CrO ₃	Fe ₂ O ₃	ZnO	SrO	Mn ₂ O 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

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

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The X-ray diffraction spectrum indicates that the raw diatomite consists of an amorphous mass of silica, the primary carbonate mineral, with minor amounts of clay minerals also present. These results are similar to the work done by El Attmani et al [3].

V. MECHANICAL CHARACTERIZATION

The measurements of mechanical resistance are carried out using a hydraulic press to determine the resistance in both traction and compression.





Fig. 5. Device for tensile test

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Fig. 6. Device for compression test The results obtained are presented in the table below.

Table III: Results of mechanical tests

$\rho(kg/m^3)$	$R_t(MPa)$	R _c (MPa)	W%
685	0,011	2,21	88

The average mechanical resistance result is low compared to that of a material used as a load carrier. At least it can be used as a filler for walls.

VI. THERMAL CHARACTERIZATION

Using the box method, we performed the tests on 0.27 mm \times 0.27 mm \times 0.04 mm samples to determine the thermal resistance.





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



Fig. 8. Experimental apparatus



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(2)

The results obtained are shown in Table 5.

TABLE IV:	Test Results	for Thermal	Conductivity

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

The following formula gives the thermal resistance R: (1) $R = \frac{1}{2}$

$$a = \frac{\pi}{\rho c_{*}}$$

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, the thermal effusivity is also deduced by the following relation:

$$E = \sqrt{\lambda \cdot \rho \cdot c_p} \tag{3}$$

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	R	а	E	C _p
(W/m.K)	(m ² .K /W)	(m/s)	$(W.m^{-2}.K^{-1}.s^{1/2})$	(J/Kg K)
0.117	1.7	1.18 10-7	339.2	1436

VII. CONCLUSION

This study enabled the determination of the various characteristics of diatomite, a material that has been used for a long time in the construction of traditional houses. The mineralogical analysis confirms the different constituents and indicates that the samples taken are pure diatomite. Mechanical tests indicate that diatomite specimens exhibit low mechanical strength; however, this material can be utilised for partitioning or filling walls in large structures. The results of the thermal tests indicate that the diatomite obtained from the Faya site exhibits good thermal properties; therefore, its use will conserve thermal energy due to its thermal insulation characteristics.

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DECLARATION STATEMENT

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