Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2023, 10(9):30-34

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Physical and Thermal Characterization of Glass Powder and Coffee Grounds for the Production of Building Materials

GNILANE THIAM*[1], NDEYE AWA SENE[1], PASCALE BALLAND[2], ALPHA OUSMANE TOURE[1]

[1]Ecole Supérieure Polytechnique, Laboratoire Eau, Energie, Environnement et Procédés Industriels, Université Cheikh Anta Diop de Dakar, Corniche Ouest BP: 5085 Dakar-Fann, Sénégal
[2]Université Savoie Mont Blanc, SYMME, FR-74000 Annecy, France
Email: thiam.gnilane@esp.sn

Abstract Concrete is generally the most used building and construction material. Its production requires a large amount of cement, releasing approximatively one ton of CO_2 to the atmosphere for every ton of cement. However, the use of glass and coffee grounds in concrete could provide an ecological and economical alternative as a new source of construction materials. The aim of this work is to determine the physical and thermal properties such as absolute and apparent densities, fineness modulus of waste glass powders and coffee grounds as well as their thermal conductivities.

Experimental studies with the helium Pycnometer and the mould method were used to determine the absolute density and apparent density respectively. These results showed that the values found for the different kinds of glass followed the same trends. For coffee grounds, however, there was a difference. Analysis of the particle size curves was also used to calculate the fineness modulus. These results show that glass powder and coffee grounds can be classified as a fine material. The box method is used to measure thermal conductivity. The obtained results showed that the samples studied can be considered as thermal insulators with respectively 0.083 W/m.K for coffee grounds and 0.09 to 0.10 W/m.K for glass wastes.

The results of the physical and thermal characterization will be useful for the development of building materials based on glass powder and coffee grounds.

Keywords Coffee, glass, density, fineness modulus.

1. Introduction

Glass is one of the most common materials found in landfill sites. It has a stable chemical composition, low water absorption, high abrasive resistance and high hardness compared to natural aggregates, according to Pellegrino et al. [1]. Coffee residues have a moisture content that varies between 55 and 80 %, which increases their adhesive power, confirming to Gomez et al. [2], but also have an abundant chemical composition in accordance with Zamora et al. [3]. It is in this context that their incorporation in the manufacture of construction materials constitutes one of the best solutions to preserve the environment by reducing air pollution and preserving our living environment. Thus the promotion and valorization of these materials has an issue of interest in several countries. This requires a coherent database for designers. Hence the need for an experimental study to characterize these materials. This involves determining their physical and thermal properties. To this end, Boukhelf et al. [4] carried out a dry particle size analysis using the CILAS 1090 particle size analyzer, which complies with standard NF EN 933-1 (2012) and is capable of detecting particle sizes ranging from 20.1 µm to 2 mm. The size of the waste varies from 8 to 50 µm. The results confirm a value of 5.56 m²/g for glass waste. However, Mejdi et al. [5] studied the physical properties of the glass powder by the laser particle size analysis, the Pycnometer, the Blaine and the nitrogen adsorption test. The results obtained show that the Blaine surface area = 593 m^2 /kg, the BET = 0.70 m^2/g, the particle size of D50 = 10.2 μm and the specific gravity =2.54. Furth8ermore, regarding the physical properties of coffee grounds, Le et al. [6] showed that the density (Gs) of coffee grounds is 1.36, the minimum and maximum dry densities are 344 and 595 kg/m^3, respectively. Thus, the coffee is considered as a natural soil. Coffee grounds particles are particularly angular in shape and have many pores on their rough surfaces. Cherdsak et al. [7] studied scanning electron microscopy, to observe the physical characteristics of dried and sieved coffee grounds particles. This work shows that the median particle size and specific gravity of coffee grounds were 0.349 mm and 1.37, respectively. Guo et al. [8] studied the thermal conductivity of concrete. Replacing river sand with fine glass particles reduced the thermal conductivity of concrete, which had a water/binder ratio of 0.23. The original concrete had a thermal conductivity of 2.0 W / (m K). The original concrete had a thermal conductivity of 2.0 W / (m K). After replacing the river sand with glass, the thermal conductivity was reduced by about 50 % to 60 %. However, Du et al. [9] determined the thermal conductivity of cement pastes. The results showed that the addition of 5 % glass powder or slag to the cement paste resulted in a 6.54% and 15.93% reduction in thermal conductivity, respectively, compared to pure cement paste. Guendouz Mohamed et Boukhelkhal. [10] measured the thermal properties (conductivity and diffusivity) using the CT scanner on three 40×80×160 mm samples according to NF EN ISO 8894-1. The results showed that concrete containing 15 % and 20 % coffee grounds are considered as insulating materials with a thermal conductivity of (λ1 W/m.K). Quesada et al. [11] used the box method to determine the thermal conductivity of the material using an isothermal enclosure called the EI700 measuring cell. The results showed that the thermal conductivity can be reduced to 0.31 W/m.K by adding 6 % coffee grounds to the base material. The objective of this work is to determine the physical and thermal properties such as absolute and apparent densities, fineness modulus of glass waste powders and coffee grounds as well as their thermal conductivities. The remaining part of our paper is structured as follows. In section 1, we first present the materials used and then describe the methods studied. Section 2 presents the results and discussion of the physical and thermal characterization of the materials. The conclusion is presented in Section 3.

2. Materials and Methods

Materials

The materials used in this study are: glass powder and coffee grounds. For the production of the glass powder, bottle glasses were collected from the mbeubeuss landfill in Dakar-Senegal and placed in saturated water for 24 hours for label removal. Initially, the waste glass particles are manually broken into smaller pieces. Then, pieces of glass obtained, were ground to powder using a Los Angeles ball mill (G-128-424305/02), containing 11 standard steel balls. During the test, the drum is rotated 500 times at a speed of between 31 and 33 rpm. The collected material was sieved and the resulting glass powder gave particle sizes from 63 micron to 1.25 mm. There are several methods of grinding glass, but the Los Angeles machine is the only one available in our laboratory. Three types of glass were used: white glass powder (WGP), green glass powder (GGP) and brown glass powder (BGP).

The samples of coffee grounds (CG) used are available locally in the city of Dakar-Senegal. Recovered coffee grounds were air-dried for 48 hours. The samples were stored under the same temperature and humidity conditions before being tested.

Methods

In order to measure and determine the physical and thermal properties of the glass powder and coffee grounds, several parameters must be carried out:

- Particle size analysis
- Absolute density, characterized by the Helium Pycnometer measurement,
- Apparent density obtained by the Cylindrical Mould of dimensions,
- Thermal conductivity measured by the box method.

- **Physical tests**

The characterization tests were carried out in accordance with the procedures described in standards N F P 94 - 041, NFP 94-053, NFP 94-054.

Particle size analysis

The test is carried out conforming to standard N F P 94 - 041. It consists of separating the agglomerated grains according to their size from the elements constituting a sample using sieves and successively weighing the cumulative refusal on each sieve. The cumulative mass of rejects on each sieve is related to the total mass of the sample submitted for analysis.

The Pycnometer method

The pycnometer method is used to determine the absolute density of samples according to the NFP 94-054 standard. It involves weighing a dried sample under study. The volume of the particles is deduced by weighing with a pycnometer (figure 1) by substituting water of known density for solid particles. The absolute density is given by the following formula:

$$\rho = \rho_w(m_2 - m_1)/(m_4 + m_2 - m_1 - m_3) \qquad (1)$$

m_1: Mass of the empty pycnometer
m_2: Mass of the pycnometer containing the test sample
m_3: Mass of the pycnometer, sample and water
m_4: Mass of the pycnometer full of water
ρ_w: Density of the water, conventionally taken as 1000 kg/m^3

The Mould method

The mould method is carried out according to the NFP 94-053 standard. The method consists in filling the mould with mass (m_4) until it overflows. The upper part of the mould is levelled with a ruler. Then the mould with its container (m_3) is weighed, the volume (V) of the sample is by convention the volume of the mould. The apparent mass volume is obtained by the following formula:

$$\rho = (m_3 - m_4)/V \qquad (2)$$

- **Thermal test**

The box method is used to determine the thermal conductivity of a material. The principle of this method is to apply a constant flow of heat through a heating resistor and to record the temperature change T(t) at the center of the same resistor in which a thermocouple has been placed (figure1)

Heat transfer modelling is used to calculate the temperature evolution at the center of the sample. An estimation method allows the calculation of the thermal effusivity, thermal conductivity and resistance.

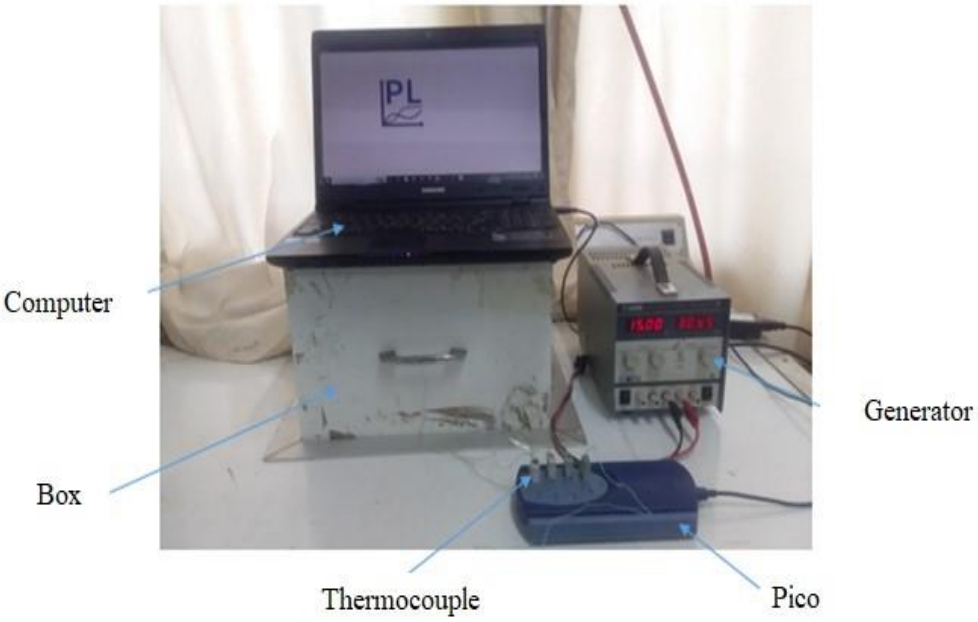

Figure 1: Experimental device

The thermal conductivity is given by the following relationship:

$$\lambda = \frac{e}{S(Tc - Tf)}\left[\frac{V^2}{R} - C(Tb - Ta)\right] \qquad (3)$$

e: thickness
S: cross-section of the sample
V: delivered voltage
R: heating resistance2
C: thermal loss constant

Tc: temperature of the heated 2phase
Tf: temperature of the cooled phase
Tb: Temperature of the box
Ta: Ambient temperature
λ: Thermal conductivity

3. Results & Discussion

The results of the particle size analysis obtained and presented in (Figure 2) show that the different kinds of glass are essentially made up of coarse elements with a fineness modulus of about 2.45. The coffee grounds, on the other hand, are made up of fine elements with a fineness modulus equal to 2.29. 8

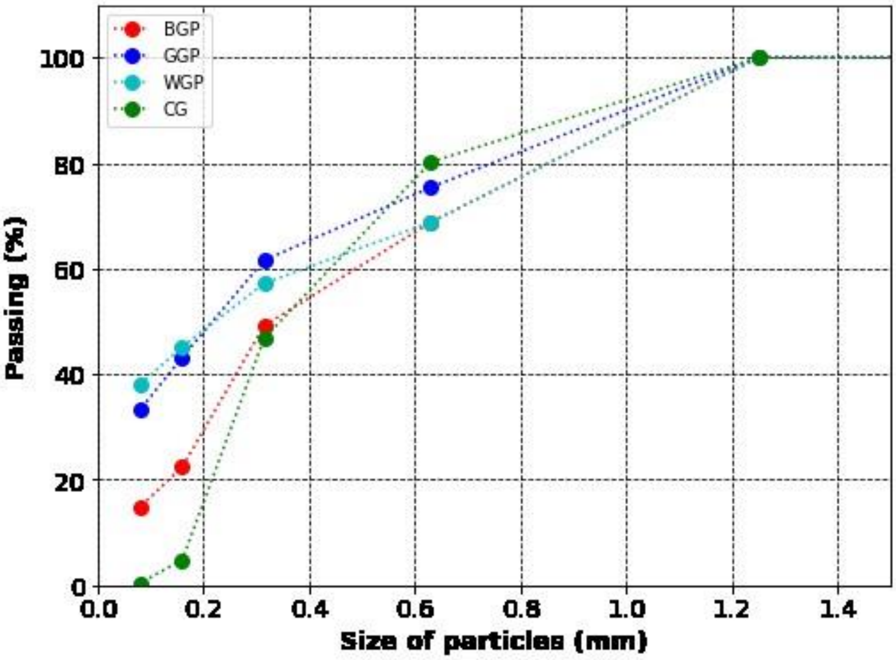

Figure 2: Size distribution of white, green, brown glass power and coffee grounds

The results of the absolute and bulk density test for glass powders and coffee grounds are presented in table 1

Table 1: Absolute and bulk density values

Materials	Apparent density kg/m^3	Absolute density kg/m^3
White glass	1246	1325
Green glass	1336	1371
Brown glass	1288	1375
Coffee grounds	324	1469

The results reveal that both materials have apparent densities of the same order of magnitude. However, coffee grounds have a lower absolute and apparent density than glass powders. Indeed, these results can be compared with those found in the literature. For example, Mageswari et al. [12] showed that glass powder has 2a density of 1310 kg/m^3. According to Premalatha et al. [13], glass has a fineness modulus of 3.16. On the other hand, Francky et al. [14] indicates that coffee grounds have an absolute and apparent density of 1160 and 430 Kg/m^3. Hanif et al. [15], state that coffee grounds have a density of less than 1900 kg/m^3. Coffee grounds are therefore less dense than glass.

Thermal conductivity was measured with a fixed voltage of 15 and 17. The results of the test are summarized in table 2.

Table 2: Thermal conductivity of the samples

Materials	Average conductivity 15volt	Average conductivity 15volt	Average heat conductivity
White glass	0.091	0.094	0.092
Green glass	0.094	0.10	0.097
Brown glass	0.092	0.094	0.093
Coffee grounds	0.081	0.083	0.082

The thermal aspect is almost absent and very little work has been done on the thermal properties of glass powder and cof2fee grounds. The thermal properties of glass and coffee grounds make these materials good thermal insulators.

4. Conclusion

This study was carried out to investigate the physical and thermal properties of waste glass and coffee grounds.
Density measurements show that the various glass powders are of the same order of magnitude, at around 1300 kg/m^3. Coffee grounds, on the other hand, are a thin, light material with high water absorption. Thermal results show that both glass samples and coffee grounds have low thermal conductivity.
The results obtained showed that waste glass and coffee grounds have satisfactory physical and thermal properties in the different types of tests carried out. They can therefore, with reference to the tests carried out, be used in the elaboration of construction materials. Nevertheless, further tests are needed to further confirm their use, i.e. their chemical composition and mechanical behaviour. This research work can be of interest, both on the economic and environmental aspects.

References

[1]. C. Pellegrino, F. Faleschini, and C. Meyer, *Recycled materials in concrete*. Elsevier LTD, 2019. doi: 10.1016/B978-0-08-102616-8.00002-2.2

[2]. F. J. Gómez-De La Cruz, F. Cruz-Peragón, P. J. Casanova-Peláez, and J. M. Palomar-Carnicero, "A vital stage in the large-scale 2production of biofuels from spent coffee grounds: The drying kinetics," *Fuel Process. Technol.*, vol. 130, no. C, pp. 188–196, 2015, doi: 10.1016/j.fuproc.2014.10.012.

[3]. 8A. Jiménez-Zamora, S. Pastoriza, and J. A. Rufián-Henares, "Revalorization of coffee by-products. Prebiotic, antimicrobial and antioxidant properties," *LWT - Food Sci. Technol.*, vol. 61, no. 1, pp. 12–18, 2015, doi: 10.1016/j.lwt.2014.11.031.

[4]. F. Boukhelf, R. Cherif, A. Trabelsi, R. Belarbi, and M. Bachir Bouiadjra, "On the hygrothermal behavior of concrete containing glass powder and silica fume," *J. Clean. Prod.*, p. 128647, 2021, doi: 10.1016/j.jclepro.2021.128647.

[5]. M. Mejdi, W. Wilson, M. Saillio, T. Chaussadent, L. Divet, and A. Tagnit-Hamou, "Hydration and microstructure of glass powder cement pastes – A multi-technique investigation," *Cem. Concr. Res.*, vol. 151, no. October 2021, p. 106610, 2022, doi: 10.1016/j.cemconres.2021.106610.

[6]. T. T. Le, S. S. Park, J. C. Lee, and D. E. Lee, "Strength characteristics of spent coffee grounds and oyster shells cemented with GGBS-based alkaline-activated materials," *Constr. Build. Mater.*, vol. 267, no. xxxx, p. 120986, 2021, doi: 10.1016/j.conbuildmat.2020.120986.

[7]. C. Suksiripattanapong, T. A. Kua, A. Arulrajah, F. Maghool, and S. Horpibulsuk, "Strength and microstructure properties of spent coffee grounds stabilized with rice husk ash and slag geopolymers," *Constr. Build. Mater.*, vol. 146, pp. 312–320, 2017, doi: 10.1016/j.conbuildmat.2017.04.103.

[8]. P. Guo, W. Meng, H. Nassif, H. Gou, and Y. Bao, "New perspectives on recycling waste glass in manufacturing concrete for sustainable civil infrastructure," *Constr. Build. Mater.*, vol. 257, p. 119579, 2020, doi: 10.1016/j.conbuildmat.2020.119579.

[9]. Y. Du, W. Yang, Y. Ge, S. Wang, and P. Liu, "Thermal conductivity of cement paste containing waste glass powder, metakaolin and limestone filler as supplementary cementitious material," *J. Clean. Prod.*, vol. 287, p. 125018, 2021, doi: 10.1016/j.jclepro.2020.125018.

[10]. G. Mohamed and B. Djamila, "Properties of dune sand concrete containing coffee waste," *MATEC Web Conf.*, vol. 149, p. 01039, 2018, doi: 10.1051/matecconf/201814901039.

[11]. D. Eliche-Quesada, L. Pérez-Villarejo, F. J. Iglesias-Godino, C. Martínez-García, and F. A. Corpas-Iglesias, "Incorporation of coffee grounds into clay brick production," *Adv. Appl. Ceram.*, vol. 110, no. 4, pp. 225–232, May 2011, doi: 10.1179/1743676111Y.0000000006.

[12]. M. Mageswari and D. B. Vidivelli, "The Use of Sheet Glass Powder as Fine Aggregate Replacement in Concrete~!2009-04-01~!2009-09-08~!2010-08-07~!," *Open Civ. Eng. J.*, vol. 4, no. 1, pp. 65–71, 2010, doi: 10.2174/1874149501004010065.

[13]. J. Premalatha and R. Srinivasan, "Properties of concrete with waste glass powder (GP) as fine aggregate replacement," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2 Special Issue 11, pp. 2308–2314, 2019, doi: 10.35940/ijrte.B1258.0982S1119.

[14]. F. Carassou, "Une récupé2ration spécifique du marc de café aurait-elle une plus-value pour la communauté : cas de l'île de Montréal," vol. 53, no. 9, pp. 1689–1699, 2015.

[15]. A. Hanif, Z. Lu, and Z. Li, "Utilization o2f fly ash cenosphere as lightweight filler in cement-based composites – A review," *Constr. Build. Mater.*, vol. 144, pp. 373–384, Jul. 2017, doi: 10.1016/J.CONBUILDMAT.2017.03.188.