CHARACTERIZATION OF AGRO-WASTES TO BE USED AS AGGREGATES FOR ECO-EFFICIENT INSULATION BOARDS

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Abstract
This work derives from the awareness of the environmental impacts caused by the construction sector. Since building products are one of the main causes of this issue, the incremental use of local natural eco-friendly materials can moderate this problem, guaranteeing lower energy consumption for production and transport. Nowadays, research is increasingly focused on the possibility of using bio-wastes to produce several materials and products such as plasters, bricks, boards, binders and glues. They can secure both more sustainable building practices and contribute to solve the problems of disposal of wastes, another cause of the environmental impacts.

The present work focuses on the characterization of some bio-wastes to assess their viability as aggregates for eco-efficient insulation boards. Knowing the properties of the raw materials allows making a more conscious choice of composite formulations according to the final requirements of the boards. For this reason, the bio-wastes from agricultural practices (agro-wastes) were studied individually. To evaluate their properties, the analysis was carried out according to RILEM Technical Committee 236-BBM, “Bio-aggregate-based building Materials” document, past literature studies and European Standards. The considered properties were loose bulk density, grain size distribution and thermal conductivity.

Four agro-wastes were chosen: spent coffee grounds, grapes press waste, olives press waste and hazelnut shells. Maritime pine (*Pinus pinaster* Ait.) chips were included as control material. They have been considered both for their potential use to produce insulation composites and for their world production, focusing on Euro-Mediterranean countries. This region was chosen taking into account where the future research will be carried out and the advantages of employing local materials. In addition, buildings of Euro-Mediterranean countries have historically low insulation performance due to the mild climate; however, climate change and other factors have led to the recognition by the users of some periods of poor indoor hygrothermal comfort. The bibliographic research allowed identifying a gap as concerns the characterization of these agro-wastes.

Both the testing methods and the properties of the considered materials are presented and discussed. In addition, the obtained results are compared with the ones of already studied materials, such as rice husk, hemp shiv and cork. Results show that the chosen materials do not have excellent insulating properties if considered individually but may probably be used to produce eco-efficient boards. The combination of them with other materials could guarantee building composites with good thermal insulation performances. The spent coffee ground differs greatly from the other bio-wastes and it seems to be more appropriate as a fine aggregate. Future research will deepen these studies and develop composites having adequate characteristics as insulation boards.

1.1 INTRODUCTION

Among the human activities that cause environmental impact, the construction sector plays a significant role [1,2]. As several past studies reported [3-6], building practices require around 40% of the global energy and resources. Considering the urgent need of mitigating the causes of the climatic crisis [7], it is extremely important to find out eco-friendly solutions for construction practices. Building materials are largely responsible for the energy consumption resulting from buildings. Their production and transport have a strong influence on their life cycle, significantly influencing the environmental impact. Choosing environmentally friendly materials and products reduces energy waste and secures healthier construction practices. Furthermore, it determines better indoor hygrothermal comfort in a passive way [6,8].

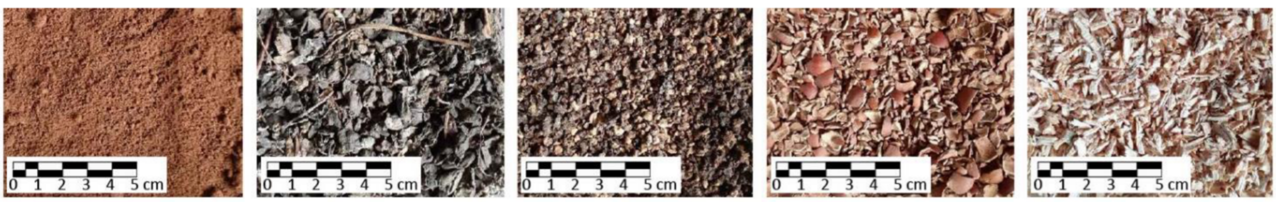
Therefore, the research interest in using bio-wastes to produce building products is growing. The possibility of using wastes from agro-industrial practices as insulation materials, considering that they are widely and increasingly produced has been extensively studied [9-11]. This is a highly efficient solution, since it both guarantees sustainability and solves the problems of disposal of agro-wastes. Agro-industrial wastes have also been used for different construction products: plasters [12,13], binders and glues [14,15], bricks [16,17] and boards [18,19]. Many of them improved the thermal insulation performance of the composite products.

For the present work four bio-wastes (spent coffee grounds, grapes and olives press waste and hazelnut shells) were characterized considering their potential use for the production of indoor insulation boards. Maritime pine (*Pinus pinaster* Ait.) chips were used as control material. They were selected considering their referenced thermal performances and their world production, focusing on Euro-Mediterranean Countries. This area was chosen for both the low insulation performance of the buildings in these countries, and considering where future research will be carried out. The use of local materials decreases the environmental impact derived from transport. The four agro-wastes were analysed individually to determine their properties as raw materials.

The analysis was carried out according to RILEM Technical Committee 236-BBM “Bio-aggregate-based building materials” document [20], past studies and relevant European Standards. Three important properties were studied: loose bulk density, particle size distribution and thermal conductivity.

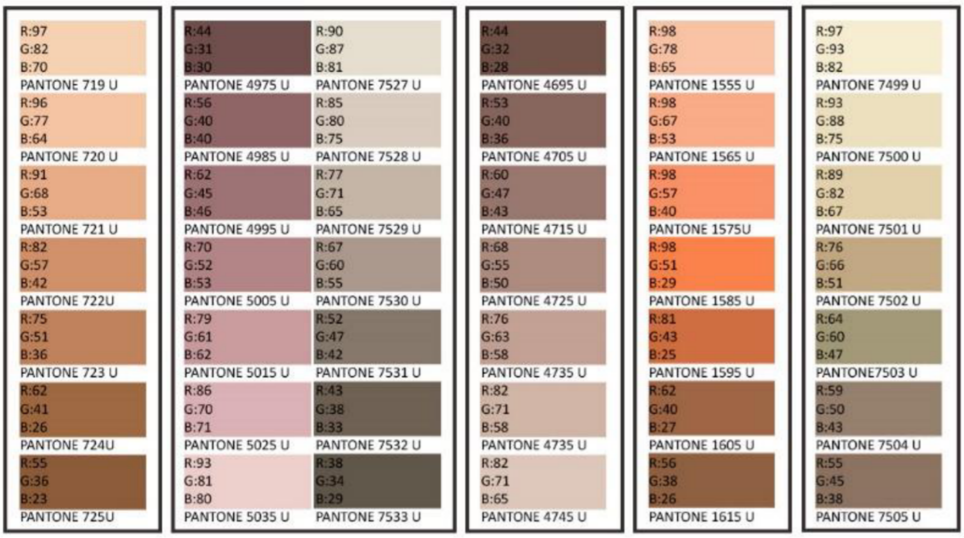
1.2 MATERIALS

Spent coffee grounds were collected from the central bar of LNEC, Lisbon, Portugal. They were spread over an absorbent paper, air-dried at room temperature for 6 weeks and regularly stirred to avoid mould growth. Grapes and olive press wastes were provided by Esporão Company located in Reguengos de Monsaraz, Portugal. They were spread over a plastic tarp for 7 and 10 weeks respectively, to air dry and regularly mixed to allow better ventilation and avoid mould growth. Olive press waste had an initial high amount of liquid content thus the longer drying period. Hazelnut shells were provided by Borges Agricultural & Industrial Nuts SA Company, located in Reus, Spain. This bio-waste was used as received. A large board of maritime pine obtained from a local wood shop (Lisbon, Portugal), was cut into 2 cm x 2 cm x 5 cm pieces and then shredded in a laminar mill five times to reach a chip dimension of less than 10 mm. Figure 1 shows the analysed materials and Figure 2 reports the colour scale according to the PANTONE Uncoated RGB scale [21].



(a) (b) (c) (d) (e)

Figure 1. Selected materials: (a) spent coffee grounds; (b) grape press waste; (c) olive press waste; (d) hazelnut shells; (e) maritime pine chips.



(a) (b) (c) (d) (e)

Figure 2. Colour scale of the studied materials: (a) spent coffee grounds; (b) grape press waste; (c) olive press waste; (d) hazelnut shells; (e) maritime pine chips.

1.3 METHODS

The bio-wastes were considered and analysed as bio-aggregates, taking as main reference the recommendations of RILEM TC 236-BBM [20] for the laboratory tests. The different materials were first placed into a pile on a flat surface. The pile was divided into quarters and then into two parts that were further divided into quarters. This procedure was repeated until having enough material to carry out the laboratory test. This sampling procedure guarantees a better mixture of the particles, avoiding the segregation between the coarser and finer ones. After that, the materials were preconditioned at 60°C until constant mass was reached (change in mass of less than 0.1% over 24 h) and then stabilised in a conditioning room (20±2°C, 65±5%) until constant mass was reached.

Particle size analysis was carried out according to Amziane et al. [20], EN 932-5 [22] and EN 933-2 [23]. The apertures of the sieves covered a wide range of sizes, from 10 mm to 0.125 mm, because the analysed materials had different grain sizes. Using more sieves allowed a more precise analysis and a better comparison between them. Samples of 100 grams of each material were spread over the first sieve (diameter=200 mm), the sieve machine was activated for 3.5 minutes and then the retained material was weighed. For each bio-waste, the test was carried out three times.

Loose bulk density was calculated considering two different methods. Adapting the method described by Amziane et al. [20] a cylindrical glass (diameter=6 cm height=11 cm) was weighted, first empty, then filled with the material until half the volume. The container was plugged, upend ten times and shaken to obtain a horizontal surface. A cardboard disc was placed on the material to mark the level of the filled cylinder. Finally, the material was removed and the container was filled with water and weighted. The bulk density was determined by Equation 1, as Laborel-Préneron et al. [24] reported. The test was repeated three times. The average value was considered significant when the coefficient of variation was less than 5%.

$$\rho_{Aggregate}\left[\frac{kg}{m^3}\right] = \frac{m_{Aggregate}}{m_{H_2O}}\rho_{H_2O} \quad (1)$$

Loose bulk density was evaluated also considering an adaptation of EN 1097-3 [25], though it is not specific for bio-wastes, by determining the ratio between the mass and the volume of the bio-aggregates. In this case, an empty cylinder with a known volume (V) was weighted (m_1). Then it was filled by dropping the material from a height of 40 cm. The cylinder was shaken to obtain a horizontal surface without compacting the material and weighted again (m_2). Loose bulk density was calculated by Equation 2.

$$\rho_{Aggregate}\left[\frac{kg}{m^3}\right] = \frac{m_2 - m_1}{V} \quad (2)$$

Thermal conductivity was determined as described by Antunes et al.[26] and Liuzzi et al. [27] using an ISOMET 2104 Heat Transfer Analyser with a 60 mm diameter contact probe API 210412, ranging values between 0.04 and 0.30 W/(m.K). A container (diameter=18.50 cm, high=5.80 cm) was filled with the material without pressing. The diameter of the container was selected considering the contact probe size and the method, reported below. The high was chosen considering that for thermal insulation products the minimum high is generally 4 cm. To evaluated the correlation between the thermal conductivity and Relative Humidity, the samples were stabilised in a ventilated climatic chamber (T=23°C, RH=50% and RH=75%). When constant mass was reached, thermal conductivity was calculated in five different points of each sample, protected from the airflow during the measurement by a cover box (Figures 3a and 3b). To validate this method, mass is controlled before and after the test to guarantee a variation of less than 0.1%. The average value of the five measurements was considered significant if the coefficient of variation was less than 5%.

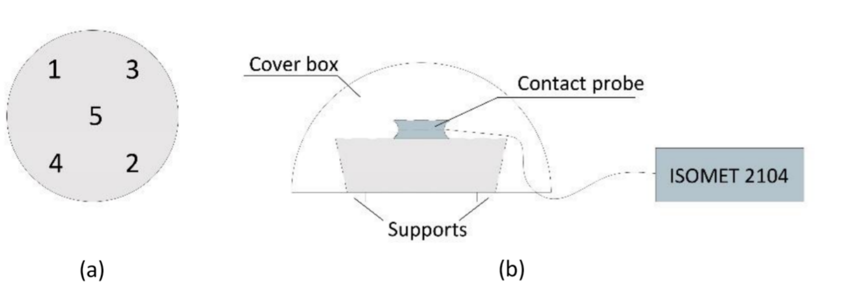


Figure 3. (a) Points where thermal conductivity was calculated; (b) Method to calculate thermal conductivity.

1.4 RESULTS AND DISCUSSION

Figure 4 presents the particle size distribution of the studied bio-wastes, and the sieves used. Spent coffee grounds have grain sizes much lower than the other materials; thus for insulation boards, they might play a better role as fine aggregates.

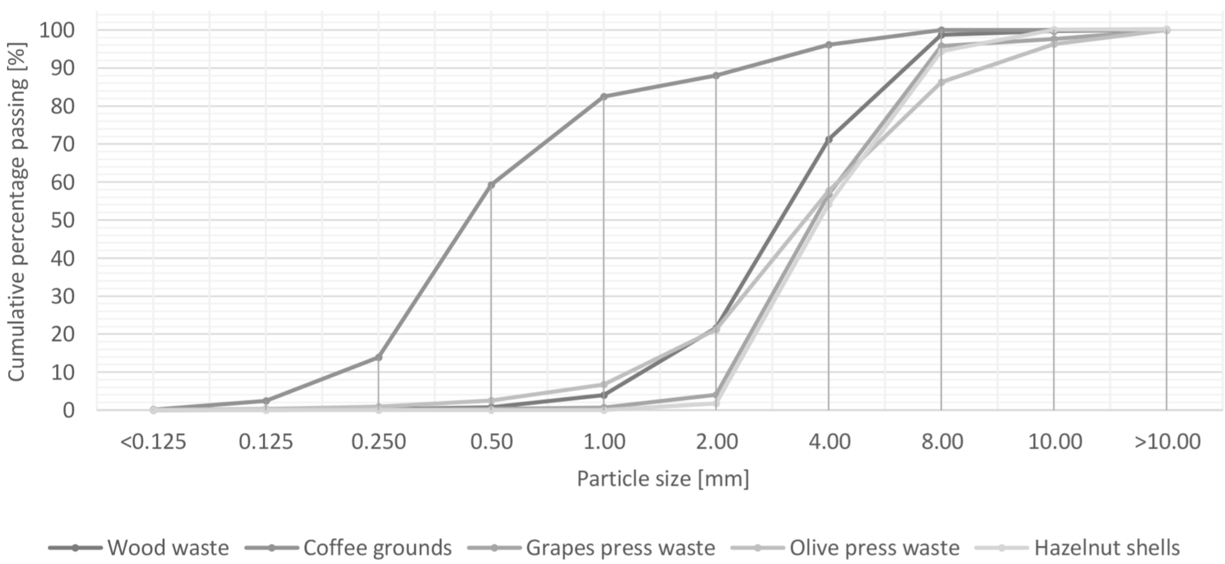


Figure 4. Particle size distribution of considered bio-wastes.

Comparing the results with the literature, it is possible to see that they are in the range of values of bio-aggregates already used in boards' production. Several past studies [18,27-29] considered bio-wastes with a grain size in the range of 0.5 mm-30 mm.