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Use of olive stone as an additive in cement lime mortar to improve thermal insulation

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ABSTRACT

The process of olive oil extraction produces olive stone, a residue which cause considerable problems of disposal.

This paper proposes and analyzes an original use of olive stone in order to improve the heat insulation performances of cement lime mortar and reduce its final density. To this purpose, the paper illustrates a set of small-scale tests, which were conducted on specimens of cement lime mortar mixed with different percentages of olive stone, in compliance with the protocols ISO. These tests allowed to evaluate the relations between thermal conductance, density and water absorption per each percentage of olive stone. It was observed that adding 70% of dry weight of olive stone allowed to reduce the average thermal conductance of cement lime mortar by over 76% and its density by around 30%.

Furthermore, tests highlighted that the decrease in thermal conductance, which was related to the increase in the percentage of added olive stone, is greater than the decrease in density. In order for the tests to be carried out, a prototype of portable measuring system was developed, which was based on the measurement of heat flow and allowed to obtain average thermal conductance values with average error below 10%.

1. Introduction

The agro-industrial economy of many South Mediterranean countries is mostly based on olive oil production and olive processing. A major problem, which significantly affects the environmental sustainability of the extraction process, is the disposal of residues, i.e. husk and vegetation water. The husk is made up of the pulp and of the olive whole stone eliminated during the extraction process; while the vegetation water includes the water contained in drupes and the one which is added during processing (Table 1). The quality and quantity of residues are closely related to the technological process adopted.

The continuous two-phase process enables to save more water than the three-phase process, which turns into less vegetation water to dispose of and husks with high values of moisture. In both cases, the olive stone is a solid residue to dispose of. The olive stone is a lignocellulosic material, whose main components are hemicellulose, cellulose and lignin [1]. It is the internal part of the drupe, which, during the phase of olive milling, is crushed and eliminated with residues. The olive stone can be the result of the direct elimination of the olive whole stone from the olive paste, an operation carried out to obtain a sweeter and more oxidation-stable oil. Finally, it can be obtained from the dedusting of the exhausted olive husk coming from olive husk factories. The size and shape of the olive stone particles depend on the milling process adopted, while the quantity ranges from 25 to 40% of the weight of the pressed olives, according to the extraction technology utilized [2]. The presence of the olive stone during the extraction process is particularly useful since it allows to obtain a more draining olive paste, thus facilitating the extraction of the oil from the mass. Furthermore, it enriches the extracted oil with peroxides enhancing the slightly bitter tones of its taste.

Owing to its fairly good calorific value, which is around 17,000 kJ kg^{-1}, it can be effectively used as a fuel, above all in the boilers of oil mills, though it requires adequate burners and, during combustion, produces a greater amount of fumes compared to other kinds of biomasses. The olive stone from the exhausted husk produced in husk factories has different characteristics.

As a matter of fact, the particular chemical processes adopted to extract the last traces of oil from virgin husk make the olive stone unsuitable to be used in small boilers, because of ignition problems, emissions of fumes and bad smells, clogging of exchangers and chimneys.

An interesting re-use of the olive stone is its mixing with clay to increase the heat insulating power of bricks [3]. Other studies [4]

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Table 1
Percentages of virgin olive husk out of 100 kg of pressed olives, according to the extraction technology used [2].

Products	Three-phase centrifugation	Two-phase centrifugation	Pressure
Total husk	45–55%	70–80%	30–40%
Water	40–55%	55–65%	24–30%
Oil	3.0–5.0%	3.0–5.0%	5.5–8.0%
Pulpy part	18–20%	12–15%	25–28%
Woody part	34–38%	25–28%	40–42%

have shown that the addition of the olive stone to bituminous concrete mixtures improves stripping resistance, durability and water and freeze-thaw resistance. Literature reports uses of olive stone to produce activated carbon and sugar [5,6], as an additive for resins [7] and as an abrasive [8].

Nevertheless, most of the latest studies have been focussed on recovering the lignocellulosic material and biomass in order to produce solid, liquid or gas biofuel. Yet, despite the environmental benefits deriving from the use of this renewable energy, some problems remain, such as air pollution caused by carbon monoxide, nitrogen oxides, soot and ash produced by combustion.

The objective of this paper is to weigh the possibility of using the olive stone as an additive in cement lime mortar in order to improve its thermal insulation efficiency. Studies carried out by the United Nations Environment Programme (UNEP) have shown that buildings account for 30/40% of the world's energy consumption, 90% of which occurs during the phase of utilization, while the remaining part is consumed during the lifecycle of building materials [9]. A considerable part of this energy is commonly used to control internal microclimate conditions, while another part is used to extract raw materials, to transport them, to make building components and, finally, to dispose of them. An estimate of the European Environment Agency [10] has shown that, if the current building methods are maintained, about 549 Mtoe will be consumed for housing and for the tertiary sector in 2020; while, if a correct saving and energy efficiency policy were implemented and aimed at promoting technical solutions of thermal insulation, a saving of 27% in housing and of 30% in tertiary building could be obtained. Therefore, interventions in this important productive sector should concern, on the one hand, the promotion of low-impact building techniques and local materials and, on the other hand, the implementation of specific solutions for heat insulation [11]. Thus, the use of the olive stone may be an economically and environmentally sustainable solution, since its re-use as an additive in cement lime mortar would allow to solve the problem of its disposal and to produce a good insulating building material.

To that purpose, the most important thermo-physical performances of cement lime mortar, mixed with different percentages of olive stone, were measured and compared in this study. In particular, a portable testing apparatus, which meets industrial rules, was created to evaluate thermal conductance. Thanks to its simple functioning and high portability, it allows to carry out rapid *in situ* evaluations of the thermal properties of materials.

2. Materials

The tested cement lime mortar was obtained by adding growing percentages of olive stone to the cement lime mortar commonly used to make plasters and floor screeds. The olive stone came from olive oil mills that used continuous extraction processes, which are particularly common in the south of Italy.

The dry mixture used to make the basic cement matrix of the tested specimens was produced and put on the Italian market, with the name Sabbiacem®, by the company Meridionali Intonaci ltd. It is commonly used in the building industry to make mortars for non-structural applications [12] (plaster for masonry, underfloorings, binders for masonry, etc.). The mixture was made up of 25% of cement (CEM II-A/L 32.5), 10% of lime and 65% of sand with variable grain size distribution (Fig. 1). The physical and chemical characteristics of the final cement lime mortar are shown in Tables 2 and 3.

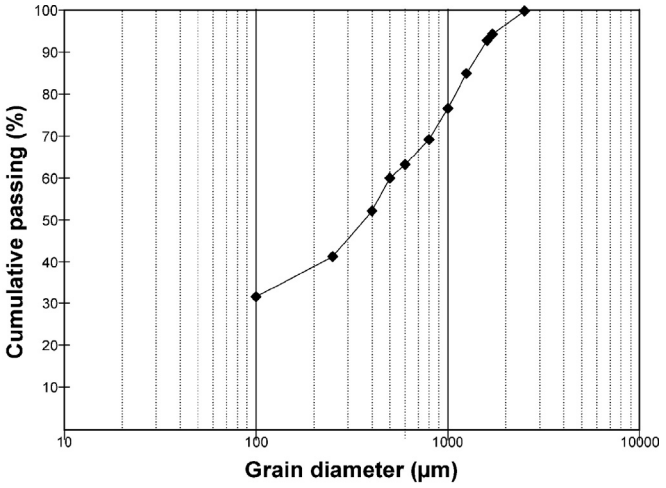

Fig. 1. Particle size distribution of sand.

Table 2
Physical properties of the cement lime mortar matrix used in the test (EN 998-1).

Final performance	Typical value
Reaction to fire	A1
Adhesion strength	>0.2 N mm^{-2}
Compressive strength	CS II
Capillary water absorption	W0
Water vapour permeability co-efficient (μ)	10–20
Thermal conductivity	1.00 W m^{-1} k^{-1}

Table 3
Chemical analysis of the main components the cement lime mortar matrix used in the test.

	SiO_2 (%)	CaO (%)	MgO (%)	SO_3 (%)	Na_2O (%)	K_2O (%)
Lime	1.03	68.53	3.29	1.37	0.09	0.05
Cement	16.23	58.28	4.65	2.35	0.38	0.35
Aggregate	0.49	52.83	2.28	0.57	0.07	0.05

The olive stone used in the tests reported in this paper (Fig. 2a and Table 4) derives from a three-phase centrifugal extraction process from "Carolea"and "Ottobratica" cultivars, which are particularly widespread in the south of Italy. After a centrifugal separation of the husk residue, the extracted olive stone underwent a natural drying process in heaps located in the open and covered by a simple shelter. The tested olive stone showed the average values of 23.67% of moisture, 1–6 mm grain size (Fig. 2b), 6399.4 N m^{-3} bulk density and no evident traces of impurities or dusts.

Table 4
Composition of fibres in the olive stone used (the range of the fibre fraction is expressed in grams per 100 g of dry matter).

Olive stone/mortar dry mixture weight ratio (%)	Water/dry mixture weight ratio (%)
Cellulose	33.45
Lignin	23.11
Hemicellulose	24.45
Ash	0.02