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Cork waste in cement based materials

Ana Mafalda Matos, Sandra Nunes, Joana Sousa-Coutinho *

Department of Civil Engineering, Faculty of Engineering University of Porto, Rua do Dr. Roberto Frias, s/n 4200-465 Porto, Portugal

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ABSTRACT

Cork is a natural material that has always been associated to mankind having huge potential and many uses. The cork industry worldwide consumes more than 280,000 t of cork a year. However, about 20% to 30% of the raw cork received at the processing units is rejected, mainly as cork dust. Finding useful applications for the rejected cork may have important economic and environmental implications. Trying to combine the advanced technology of self-compacting concrete and use of this waste from the cork industry, this study concerns the possibility of using cork powder as a substitute for fines in mixtures of self-compacting concrete. An experimental program was carried out to assess the behavior of this material in the mixture and define properties in terms of strength and durability of self-compacting concrete containing cork powder. It was found that it is possible to use an abundant waste material from the cork industry, cork powder, as fines in Self Compacting Concrete resulting in a good strength level (C 30/37) and suitable durability for common applications.

1. Introduction

Cementitious materials, mainly in the form of concrete, are the most successful materials in the world. Every year more than 1 m^3 is produced per person worldwide. The huge volumes of cement and concrete produced mean that cement production accounts for some 5–8% of man-made CO_2 emissions. Therefore there is increasing pressure to innovate to improve sustainability [1].

Despite the existence of large amounts of industrial waste such as blast furnace slag, fly ash, silica fume, slag and agricultural residues such as rice husk ash, which have been used for many years in large amount as raw materials and components in the cement industry, there are still many other industrial wastes not used yet [2].

Cork is a natural, organic and lightweight product with high dimensional stability. These features allow cork to be used in a wide range of applications, such as, lightweight filler in thermal insulating solutions, aggregate for concrete, reduced weight concrete panels and also for acoustic insulation in floating floors. But cork also has other important characteristics in addition to being a natural and ecological product. It does not release noxious fumes or odors and it is a material that remains unchanged while maintaining its efficiency over long periods of time [3].

World cork industry annually consumes more than 280,000 t of this natural material. However, it appears that a significant amount of the raw material received in plants (20% to 30%) is rejected, mainly in the form of cork powder [3]. "Cork powder" is a term used to cover all cork waste comprising crude cork impurities, cork material powder, cork particles having dimensions lower than permitted for granulates (usually lower than 0.5 mm), and sometimes larger pieces. "Cork powder" is produced in all industrial cork processing systems originated in various industrial operations and based on different cork types which are used in the production of multiple cork products. This material has been used mainly as combustion fuel in cork industries, while a small fraction is used as filling agent (mixed with adhesives) for the poorer quality cork stoppers and for linoleum production [4].

Since Portugal is the world's largest cork producer, with 60% of the total cork tree area providing about 80% of the cork produced in the World [4], it may prove economically interesting to find alternative uses for the use of industrial waste from the processing of this material.

Cork granules have been studied for application in other industries, namely in the construction industry.

Reis et al. studied the effect of cork and rice husk ash micro-particle fillers on the mechanical properties of polyester based composite. Filled materials exhibit fragile behavior and flexure strength much lower than the polyester matrix, and decreasing significantly when the filler content increases from 1 to 5%. Strength loss is more pronounced for cork powder than for rice husk ash filler. Using cork powder the fracture toughness decreases significantly with filler content [5].

Branco et al. [6] developed a research project evaluating the physical and mechanical properties of waste cork, and exploring its potential benefits when used as aggregate in production of concrete. Different concrete mixtures were prepared, containing different amounts of cork granules. Two types of cork were considered: natural and expanded cork. Compressive strength at different ages was determined showing that strength of concrete tends to decrease as the amount of cork increases. This effect is more noticeable when cork powder replaced

* Corresponding author.
E-mail addresses: anamatos@fe.up.pt (A.M. Matos), snunes@fe.up.pt (S. Nunes), jcouti@fe.up.pt (J. Sousa-Coutinho).

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coarse aggregate. The use of expanded cork leads to further reductions in terms of strength.

González et al. [7] determined the physical and mechanical properties of concrete made with different proportions of cork powder. The resulting material showed very low mechanical strength due to very high water cement ratios that were required in practice, caused by the great amounts of water absorbed by cork powder. However this material may be apt for certain agricultural uses, such as in the manufacture of pavement for playgrounds and parks, or certain kinds of structures used in livestock breeding.

Moreira et al. [8] carried out an experimental study on the use of expanded cork granule waste with cement-based mixtures to produce lightweight screeds for overlaying structural concrete slabs. Experiments were carried out on 3 cement dosages of 150 kg/m^3, 250 kg/m^3, and 400 kg/m^3, incorporating expanded cork granules as replacement of part of the sand. Three additional mixtures without cork were prepared and used as reference. The experimental results of the mechanical and hygrothermal characterization showed that replacing sand by expanded cork granules in the screed mixtures lowers their hardened density, compressive strength and thermal conductivity. It was also shown that the screed mixtures with the lowest cement content have lower thermal conductivity. These findings demonstrate the advantages of lightweight screeds in terms of reducing construction weight and cutting energy costs. For very low cement content the screeds were found to be unsuitable for use as final floor coverings because of their low compressive strength.

Carvalho et al. [9] presented an experimental analysis of the cyclic behavior of a novel composite material made from traditional mortar with incorporation of granulated cork. Specimens with 0%, 15%, and 30% of cork addition, in volume of the mixture, were prepared and tested. The authors explored the potential use and application of this composite material, taking advantage of its energy dissipation capabilities, to be used in the construction of walls in order to reduce their seismic vulnerability.

The viability and feasibility of combining waste cork with cementing materials considering fresh and hardened material properties, was also investigated. It could be concluded that the greatest 3 and 7 day cube strengths were achieved by 24 h moisture saturation followed by draining of the cork, prior to use in concrete. Finer cork sizes were most beneficial to achieve optimum mechanical and transport properties. However, high permeability values indicated that concrete-cork composites considered in this study may be vulnerable to poor durability performance [10].

Cork waste as combustion material produces ash which is usually landfilled. This ash could be used in cement based construction materials contributing to sustainability. Work carried out with Portuguese cork ash used as 10 and 20% cement replacement in mortar led to acceptable strength for 10% cement replacement with cork ash (5% loss at 90 days, compared to control) but most durability properties (tested up to 6 months according to test type) reduced performance probably due to a broader pore structure caused by coarse particles in the ash which tested non-pozzolanic. Moreover, the cork waste ash studied did not present the necessary requirements in terms of chemical properties considering several standards. Therefore this cork waste cannot be used as a pozzolan or as a filler in cement based materials [11].

The aim of the present study concerns further innovating research on use of cork waste in cementitious materials, in particular cork powder, as replacement for fines in mixtures of self-compacting concrete. An experimental program was carried out to assess the behavior of this material in concrete mixtures and measure properties in terms of strength and durability.

Table 1
Chemical and physical properties of cement and limestone filler.

	CEM I 42.5 R	Limestone filler
LOI	2.61	
Insoluble residue	1.33	
SiO_2	20.36	<0.5
Al_2O_3	5.10	
Fe_2O_3	3.12	
CaO	62.72	>98
MgO	1.81	
Na_2O		<0.06
K_2O		
SO_3	3.44	
Cl	0.012	<0.001
Free limestone	1.62	

2. Materials and methods

2.1. Materials

Type I 42.5R Portland cement (specific gravity 3.16 g/cm^3) and commercially available limestone filler (over 98% $CaCO_3$, specific gravity 2.7 g/cm^3) were used as binders. Chemical and physical properties can be seen in Fig. 1 and Table 1. A reactive siliceous sand (CEN EN 196-1 [12]) was used as aggregate on mortar preliminary tests.

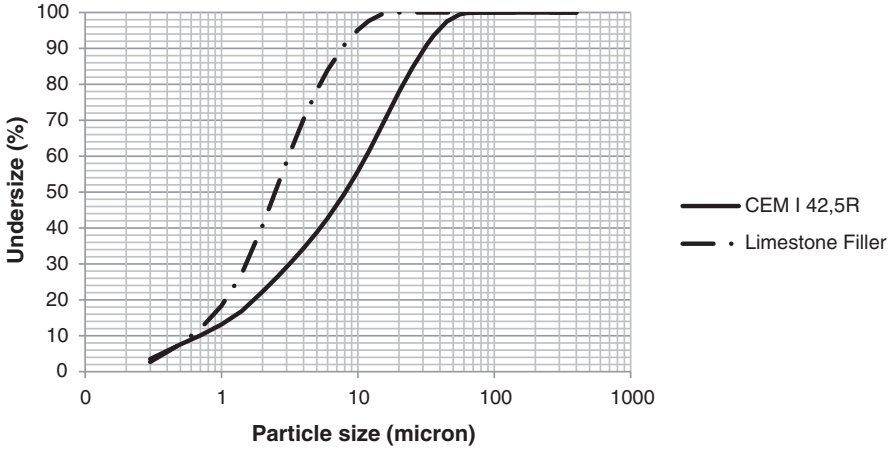

Fig. 1. Particle size distribution of cement and limestone filler.