Durability of sustainable mortars made with filler from different industrial by-products

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Keywords: mortar, sustainability, capillary water absorption, water vapour permeability, shrinkage.
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1. Introduction

Regarding to the environmental awareness increase, it is essential to explore alternative solutions to waste disposal problem. Innovation and research are the key to the implementation of a circular economy in the construction sector, which is fundamental for the sustainability of the current world.

This study investigates the possibility of using various types of waste generated from different industries as filler in mortars as common construction material. Hence, it has been manufactured different mortars. As reference mortar a siliceous filler, after, this one was replaced by filler with diverse nature; ceramic from construction and demolition waste treatment plant; waste from the drying process of the aggregate used in the manufacture of hot-mix asphalt, hereinafter called recovery filler; and granite and marble, from their corresponding industrial processes (splitting, sawing and polishing). The use of these by-products as filler in mortars have been studied by diverse authors in cementitious base materials. Jackiewicz-Rek *et al* (2015) studied the incorporation of ceramic filler from sanitary industry in mortars, up to 20% of ratio replacement resulted in lower shrinkage. Esquinas *et al* (2018) found that the inclusion of recovery filler in self compacting concrete led to a lower shrinkage values over time than the mix with siliceous filler. Li *et al* (2018) suggested that the addition of marble dust would substantially reduce the shrinkage and improve the impermeability of the mortar produced. Gupta and Vyas (2018) obtained in test on drying shrinkage, that the shrinkage increased as higher replacement of granite powder by natural sand. Other authors such as Torres-Gómez *et al* (2016) studied others wastes as a non-conforming fly ash (Nc-FA) from a coal fired power plant as filler in mortars and recycled sand from masonry waste.

The main objective of this work is to compare the effects of the use of different fillers from different industrial by-products in the manufacture of mortars. These were compared with a mortar made with a commercial siliceous filler by means of the workability and entrained air content tests in fresh state and the following tests in hardened mortar: capillary water absorption, water vapour permeability and shrinkage (up to 77 days).

2. Materials and methods

The dosage for the manufacture of the mixtures was made in a proportion by weight: 3500 gr of natural sand, 500 gr of cement and 300 g of filler. The amount of water was adjusted experimentally to achieve a consistency of 175 ± 10 mm (UNE-EN 1015-3: 2000). A commercial plasticizer (NEOPLAST) was mixed directly into the water at a content of 0.1 mL. The water to cement plus filler ratio was kept constant between 0.85 and 0.90. The cement used was CEM I 52.5 R. The mixing process was defined in a previous research of Jiménez et al. (2013). A standard mixer was used according to UNE-EN 196-1:1996.

Mixes (Table 1) were produced in the laboratory. Table 1 shows the specific gravity of the fillers used and the tests conducted, four specimens were used for each test. Workability and entrained air content (and fresh density) in the mortars were obtained after manufacturing. The capillarity water absorption and water vapour permeability were conducted after 28 days. Shrinkage was measured after 3, 7, 14, 28, 49 and 77 days of curing. Samples were stored before being tested (or measured) in a chamber at constant temperature (20 °C ± 2 °C) and relative humidity of 65% ± 5%.

Table 1. Composition of the samples and properties studied.

Mixes	Filler	Specific gravity	Methods	
			Fresh state	Hardened state
M-FS (ref)	Siliceous	2.611	Workability (UNE-EN 1015-9:2000)	Capillary water absorption (UNE-EN 1015-18:2003)
M-FC	Ceramic	2.522		
M-FG	Granite	2.449	Entrained air content and density (UNE-EN 1015-7:1999)	Water vapour permeability (UNE-EN 1015-19:1999)
M-FM	Marble	2.204		
M-FR	Recovery	2.693		Shrinkage (UNE 83831:2010 EX)

3. Results and discussion

Table 2 shows the properties of the fresh state (workability, density and entrained air content) and hardened state (capillary water absorption, water vapour permeability and shrinkage) in the mortars produced. The fresh density values in mortars are strongly related to the density of the filler used, as expected. The replacement of Siliceous filler with the others shows that the workability decreases, ranging between more than a half respect to marble filler and less than a 7% respect to recovery filler in percentage of minutes. The capillary water absorption increased slightly in M-FC and M-FG and by 23% in M-FR respect to reference mortar, whereas it was reduced by 22% in M-FM. The water vapour permeability is reduced in all mortars with respect to the reference mortar, being 35% the greatest decrease in M-FM. These properties are not limiting for indoor use.

Table 2. Fresh properties and hardened properties of the mortar mixes produced

Methods \ Mix	M-FS	M-FC	M-FG	M-FM	M-FR
Workabality (min)	206.5	179.8	152.3	92.3	192.5
Fresh density (g/cm^3)	1.98	1.90	1.85	1.81	1.97
Entrained air content (%)	7.8	6.8	5.2	2.7	8.0
Capillary water absorption $Kg/(m^2 \cdot min^{0.5})$	1.01	1.03	1.08	0.79	1.24
Water vapour permeability ($10^{-11} \cdot kg/m \cdot s \cdot Pa$)	1.11	1.01	0.85	0.72	0.90

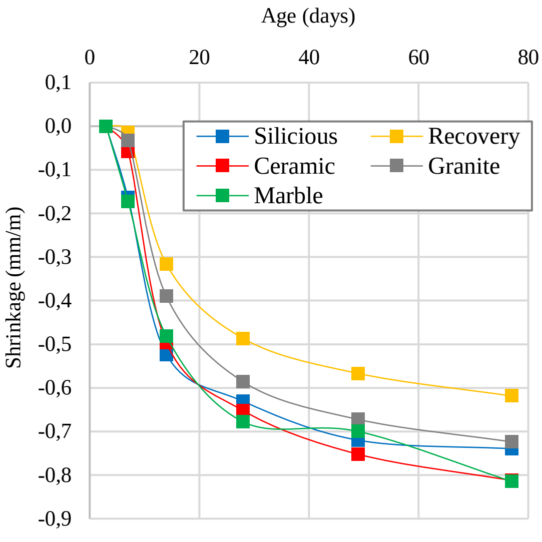

Figure 1. Shrinkage of mortars over time

Shrinkage is a phenomenon that causes dimensional variation in cementitious base materials, which makes it one of the most significant aspects of mortar durability. Shrinkage values represent the combination between the desiccation and the carbonation which evaluate its capacity to support drying. In Torres-Gómez´s *et al* (2016) study, shrinkage rise after 77 days were negligible. Figure 1 shows the shrinkage results for the five specimens after 77 days. It is shown that the replacement of siliceous filler with granite and recovery filler decreases shrinkage in mortars and increases in mortars with ceramic and marble filler in 10% approximately. This in accordance with Esquinas *et al* (2018) and Jackiewicz-Rek *et al* (2015).

4. Conclusions

The incorporation of the different by-products studied as filler in mortar has been studied as a viable use in terms of durability. The shrinkage performed a good behaviour. All mixes shrinkage values were less than 110 % of the reference mortar made with commercial siliceous filler. Therefore, the use of the by-products studied in mortars manufacturing could be a viable alternative that would help increase the sustainable development in the construction sector.

5. References

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