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

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Keywords: mortar, circular economy, adhesive strength, mechanical properties over time.
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1. Introduction

Circular economy is based on achieving integrated the use of waste as a secondary raw material, making it possible to face the environmental demands stated by the European policies. It has been indicated that the objective aimed is to optimize natural non-renewable resources and waste recovery (Union Innovation, 2014) in all economic areas.

In the construction sector, mortar is very important due to it can have multiple uses, including fixing or binding building blocks, as well as wall and ceiling coatings which serve as a regularization layer, later to be painted. Mortar is also used as glue to fix plates and coat walls or floors. Most multiple-use mortars are composed of cement, sand and water in varying amounts, according to the area of use and application.

This study has carried out an evaluation of the different wastes from different industries as supplementary cementitious materials in mortars. For this purpose, it has been used a siliceous filler as reference mortar mix. This filler was replaced in the rest of the mixes by filler with different origins; ceramic from construction and demolition waste (C&DW) treatment planta; 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). Many authors studied the use of these by-products as sustainable binder in in cementitious base materials in terms of durability. For instance, Jackiewicz-Rek *et al* (2015) studied the incorporation of ceramic filler from sanitary industry in mortars, up to 20% of ratio replacement resulted in significant increases in flexural and compressive strength. Esquinas *et al* (2017) found that the inclusion of recovery filler in self compacting concrete gave lower mechanical properties than the mix with silicious filler. Corinaldesi *et al* (2010) obtained a decrease of 20% compressive strength after 56 days in 10% replacement of cement with marble. Mármol *et al* (2010) concluded that up to 10% of granite filler can be substituted without loss of compressive strength at 28 days.

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 following properties of mortars: resistance to compression and bending over time (up to 180 days), strength and adhesive density; fresh and hardened.

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 gr of filler. The amount of water was adjusted experimentally to achieve a consistency of 175 ± 10 mm (UNE-EN 1015-3: 2000). A 0.1 mL of commercial plasticizer (NEOPLAST) was added into the water. 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. Density of fresh mortar were obtained after manufacturing. The evolutions of mechanical characteristics, compressive and flexural strength, were studied over time after 7, 28, 90 and 180 days of curing. It was also studied the adhesive strength and density in hardened mortar at 28 days of curing. Samples were stored before being tested in a chamber at constant temperature (20 °C ± 2 °C) and relative humidity of 65% ± 5%. In addition, the environmental risk assessment of the filler used was conducted by means of comparing the release levels of pollutant elements with the limits stablished by the Landfill Directive DC 2003/33/EC, which allows classify the materials according to their hazardous potential. The ceramic, granite and marble fillers were classified as non-hazardous materials, whereas siliceous and recovery filler were classified as inert.

Table 1. Composition of the samples and properties studied.

Filler	Specific gravity	Mixes	Properties: Physical	Properties: Mechanical
Siliceous	2.611	M-FS (ref)	Density in fresh mortar (UNE-EN 1015-3:2000) Density in hardened mortar (UNE-EN 1015-10: 2000).	Compressive and flexural strength over time (UNE-EN 1015-11: 2000) Adhesive strength (UNE-EN 1015-12: 2000)
Ceramic	2.522	M-FC		
Granite	2.449	M-FG		
Marble	2.204	M-FM		
Recovery	2.693	M-FR		

3. Results and discussion

Figure 1.a) shows density in fresh mortar, and adherence and density in hardened mortar. Fresh density values in mortars are strongly related to the density of the filler used, as expected. Comparing the values obtained in the reference mortar with the other mortars, it can be seen an improvement in the adhesive strength.

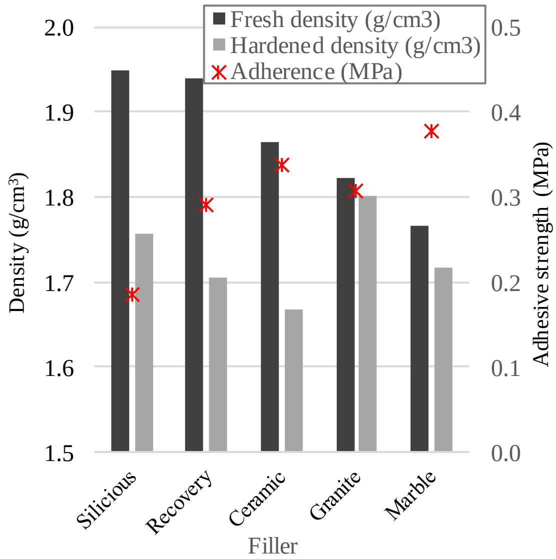

Figure 1.a) Density in fresh mortar, and adhesive strength and density in hardened mortar.

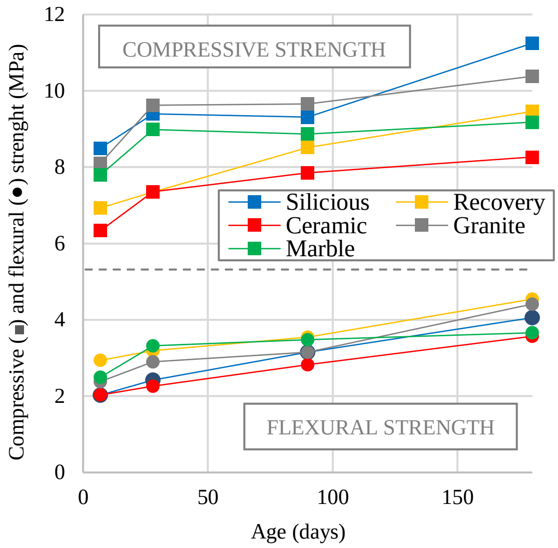

Figure 1.b) Mechanical properties over time

Figure 1.b) shows the evolution over time of mechanical properties. All the mixes presented an improvement over time in the mechanical properties. All compressive strength mixes values were above 8 MPa after 180 days. The increase of flexural strength between 28 and 180 days were greater in M-FC, M-FG and M-FR mixes than in reference mortar.

4. Conclusions

The incorporation of the different by-products studied as filler in mortar has been studied as a viable use. The compressive and flexural strength over time performed a good behavior. All mixes exhibited higher values than reference mortar in adhesive strength test. Given the fact that, in case these wastes are disposed at landfills and not being classified as inert material according to the Landfill Directive, their re-use as filler in mortar are presented as a sustainable solution.

5. References

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