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Properties of ultra-high performance concrete made with granite cutting waste

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1. Introduction

In recent decades, the overexploitation of the natural resources has reached unsustainable levels. Overexploitation depletes resources, destroys natural habitats and pollutes the environment. For these reasons, the European Union (EU) is enforcing policies to reduce the impact of waste materials on the environment while improving the efficiency of re-source management within the common territory. In 1973, the EU launched a corrective policy, called the Environment Action Program, currently in its seventh edition (European Union, 2013).

For these reasons, and because the UHPC, from an ecological point of view, it could not be a sustainable material since it requires high amounts of cement, that contribute to a high energy consumption. The development of a more sustainable UHPC incorporating waste materials that requires a smaller manufacturing energy consumption is currently being investigated (Pyo, 2017; Randl, 2014).

The use of micronized quartz (SiO2 crystalline) in the manufacture of UHPC allows to reduce the volume of cement and complete the granulometric curve in the smallest sizes thanks to the size of its particles (<40 µm). So it is achieved by increasing the packing density of the matrix and achieving greater compactness, stability and durability in the concrete. However, the utilization of micronized quartz, have a high energy cost and increase the CO2 footprint due to their grinding process. It can also cause serious health problems, such as silicosis, due to its repeated inhalation. For these reasons, different studies have been carried out to replace them with other materials (Burroughs, 2017; Soliman, 2016; Vaitkevicius, 2014).

Due to these reasons and because, after the building sector, the mining industry sector is the activity that generates the largest amount of waste, the viability of using waste from a granite quarry as a partial or total substitution of the micronized quartz to produce a more sustainable UHPC has been analyzed.

2. Material and methods

The cement used was CEM I 42.5 R/SR. Two silica sands with size fractions of 0/0.5 mm and 0.5/1.6 mm were used. As additions, densified silica fume and micronized quartz powder were used. To achieve optimal workability, a polycarboxylate superplasticizers were used. The short steel fibres used in this study had a diameter of 0.2 mm and a length of 13 mm. Finally, granite powder waste (FG) obtained from the cutting process of granite blocks was used as a supplementary material.

To carry out this study, a reference mix was designed that ensures a self-compacting fresh concrete with a compressive strength above 115 MPa. Once the characteristics of the control concrete were verified, 35%, 70% and 100% of the micronized quartz was replaced by the same volume of granite powder. **Table 1** shows the UHPC composition.

Material	Control	35% FG	70% FG	100% FG
Cement	1	1	1	1
Sand 0/0.5	0.378	0.378	0.378	0.378
Sand 0.5/1.6	0.706	0.706	0.706	0.706
Harina sílice	0.281	0.183	0.084	-
Silica fume	0.219	0.219	0.219	0.219
Granite powder	-	0.098	0.197	0.281
Water	0.214	0.214	0.214	0.214
Superplasticizer	0.0125	0.0125	0.0125	0.0125
Steel fibres	0.200	0.200	0.200	0.200

Table 1. UHPC composition.

Finally, the experimental program was developed. Hardened density of UHPC, compressive strength and flexural strength test were carried out. To characterize the mortar matrix, a scanning electron microscope (SEM) with magnifications of ×30, ×200 and ×500 was used.

3. Results and conclusions

Table 2 shows a summary of the results obtained in this work. The incorporation of granite cutting waste, as a replacement of micronized quartz, has not impact on the hardened density of UHPC. The variations are very small, less than 1.5%, and they are due to the variability of the experimental results.

The average compressive strength in all the mixes with granite waste is increased. This increase in compressive strength oscillates between 8.5%, for ratios of 35% and 70% and 4.5% for 100%.These slight increases can be due to the better compactness of the mixes when the granite cutting waste is incorporated.

The flexural strength increase when the substitution ratio is 35%, and even the values obtained for 100% substitution are acceptable. These good results obtained may be due to the better adhesion with the cement paste, as a consequence of the more irregular shape of the granite particles and the presence of the short steel fibres.

Serie	Control	35% FG.	70% FG	100% FG
Density (kg/m3)	2410	2380	2390	2410
Compressive strength (MPa)	117,2	127,8	127,6	122,5
Flexural strength (MPa)	23,0	24,4	23,1	21,6

Table 2. Experimental results.

In view of the results obtained in this study, granite cutting waste, instead of the micronized quartz powder usually used, is a viable alternative for the manufacture of expectedly more sustainable UHPC.

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