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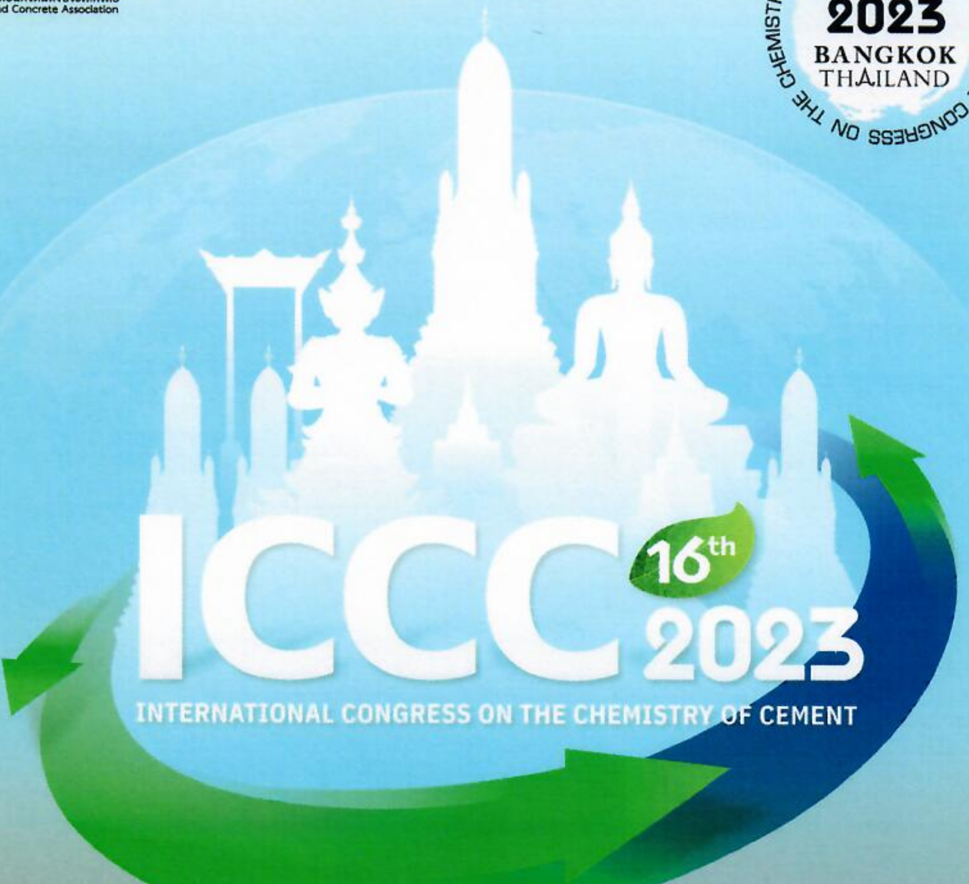

ICCC 16th 2023

INTERNATIONAL CONGRESS ON THE CHEMISTRY OF CEMENT

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Further reduction of CO_2-emission
and circularity in the cement and concrete industry

SEPTEMBER 18-22, 2023

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The 16th International Congress on the Chemistry of Cement 2023 (ICCC2023)
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CDW waste as retardants of ions harmful to cement

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ABSTRACT

Circular Economy promotes the use of industrial materials during various phases of their active life. Construction and demolition waste (CDW) are one of those materials that can be reused several times without losing their properties, even improving them, by participating as substitutions in the Ordinary Portland Cement (OPC). The large volume of CDW wastes makes this substitution one of the most valued in the world of cement at present; it is for this reason that two types of aggregates, siliceous and calcareous, have been selected as potential substitutions in the OPC. In all cases, it is a question of obtaining easily accessible pozzolanic cements, with little contamination and great economy. In this work, binary mixtures of OPC and CDW waste have been prepared, manufacturing mortars that have been studied by means of XRD, XRF, SEM/EDX, and ion diffusion. The results obtained so far indicate that CDW's are suitable for substitution in the OPC in variable proportions that their use improves the slowing down of diffusion for certain ions, so that can link the pore size with the capture of these ions, considering certain pores as traps for the diffusion of polluting ions.

KEYWORDS: *CDW waste, diffusion, tomography, pozzolan, porous size.*

1. Introduction

Concrete is the most used material in construction. It is characterized by a variable total porosity between 10-30%, depending mainly on the water/cement ratio and the curing conditions. The porous capillary network is the access channel through which aggressive agents degrade the cement matrix. The main aggressive agents are related to the presence of chlorides, sulfates, and CO_2, which have the capacity to react with the anhydrous and hydrated phases of the cement and cause a progressive deterioration of the constructions (Onah et al. (2023)). Therefore, the cement matrices present low resistance to aggressive environmental agents due to the presence of high portlandite contents (24-27% of the total). One of the solutions to increase resistance against aggressive environments is the use of standardized active additions (fly ash, natural pozzolan, silica fume, etc.) and non-standardized (ceramic wastes, CDW wastes, coal mining waste, agroindustrial residues) (Villar et al. (2008), Snellings et al. (2012), Frias et al. (2018)), which, through the pozzolanic reaction, produce secondary hydrated phases that refine the porous structure, preventing or delaying their entry. Currently, one of the types of waste that is generating special attention from the scientific community and the construction sector is construction and demolition waste (CDW), due to its large annual volume (350 mtns in Europe), generating significant environmental, economic, and social problems when it accumulates in landfills. In this line of research, this paper analyzes, for the first time, the behavior of binary cement mortars made with 7% CDW pozzolan, which were exposed to the environment for 12 months in the city of Madrid (Spain).

2. Materials and methods

2.1. Materials

To carry out this research work, two fine fractions of concrete (<5 mm) from Spanish CDW Treatment Plants have been selected: siliceous concrete (HsT) and limestone concrete (HcG). To obtain the binary cements with a 7% substitution for each of the CDW pozzolans, a commercial cement type CEM I 52.5R was used. The cement mortars were manufactured and cured according to current regulations with a water/binder ratio of 0.5 and the 4x4x16 cm prismatic specimens were previously cured under water for 28 days. Subsequently, the specimens were exposed to outdoor and indoor environments for 12 months (January 2022-December 2022).

2.2. Methods

All samples were studied using X-ray diffraction (XRD) and scanning electron microscopy (SEM), equipped with an energy dispersive X-ray (EDX) analyzer. At the end of the time, a *line scan* was performed on the parts exposed and not exposed to air in the different environments. The data of each element correspond to the average of two analyzes, due to the variability that exists in each measurement field, which is repeated in a variable number, every 491 nanometers, which is the field distance.

3. Results and discussion

The chemical composition by XRF of the fine fractions of the CDW of recycled concrete used as starting materials are collected in Table 1.

Table 1. Chemical composition of starting materials by XRF analyses (HsT = siliceous concrete; HcG = limestone concrete; LOI = loss on ignition).

(%)	SiO_2	Al_2O_3	CaO	Na_2O	K_2O	P_2O_5	Fe_2O_3	MgO	SO_3	TiO_2	MnO	LOI
HsT	49.97	8.98	18.65	0.80	3.35	0.11	2.30	1.37	2.53	0.28	0.04	11.50
HcG	9.34	2.88	50.32	0.18	0.47	0.03	1.20	1.12	0.85	0.14	0.09	33.20

The mineralogical quantification of the wastes by the Rietveld method shows that the HsT and HcG concrete wastes are made up of calcite, mica, feldspar, and quartz in different proportions, according to the nature of the primary aggregate (Caneda et al. (2022)). In all samples a sequential analysis from one end of the test piece to the other, an oscillation of the different measured elements is observed. However, and according to the range of variation, three groups can be distinguished: 1) Si and Ca: they are the ones that more varying in ranges that oscillate between 20 and 70%. Both are complementary, that is, an increase in one implies a decrease in the other; 2) ions with concentrations between 9 and 2%. Aluminum, sulphates, iron, and potassium are usually found in this range, the latter only in certain cases (if the concentration is low, it will form part of the so-called group 3). Finally, elements in concentrations lower than 2%, where magnesium, chloride, manganese, sodium, titanium, barium are usually found.

3.1. Mobility within OPC mortar.

The differences between ion diffusion in the laboratory samples present, for sulfate, Fe and Al (all existing in the initial concrete wastes), a behavior similar with three concentration maxima along the profile: an initial moment, another at a medium distance from the specimen and the last one, before covering the total distance. On the other hand, in the environment samples, in the group 2, appears K with three maximum concentrations, which indicates that it absorbs potassium ions from the environment with a change in the behavior of iron and sulfate since it only a maximum concentration appears, stabilizing later. The elements of group 3 are different, thus chlorides are detected on the outside with two moments of diffusion, while Ti appears on the inside at one end, as well as Mg and Na with constant amounts throughout the mobilization.

3.2. Mobility within 7% HcG mortars.

This mortar from a 7% substitution in the OPC by HcG limestone concrete waste, has a different mobility in the elements of group 2 for the sample with natural exposure and the sample exposed in the laboratory; in the latter, Al is the one that is mobilized in three successive moments, while Fe and sulphates remain constant in the profile, except in an area close to the surface where Fe increases its concentration and then decreases and reaches a constant concentration. On the other hand, in the environment sample there is a different behavior for sulfate and Al with two maximums, beginning and middle of line scan. In the elements of group 3, the environment sample presents chlorides, Mn and Na, with three critical moments. It differs from the laboratory sample that offers a variation of Ti in the distal zone (Figure 1).

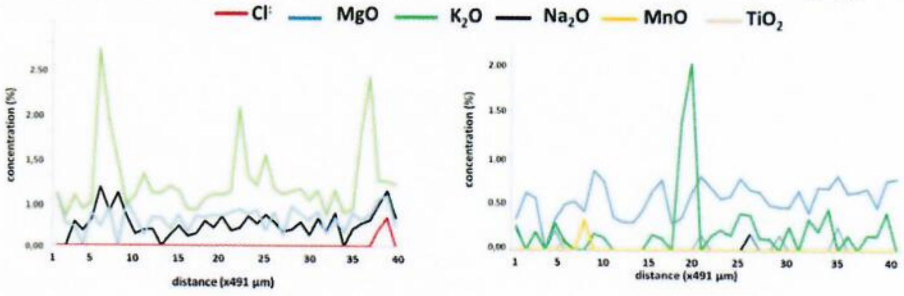

Figure 1. Mobility of ions in HcG mortar samples located in the laboratory room (left) and environment (right).

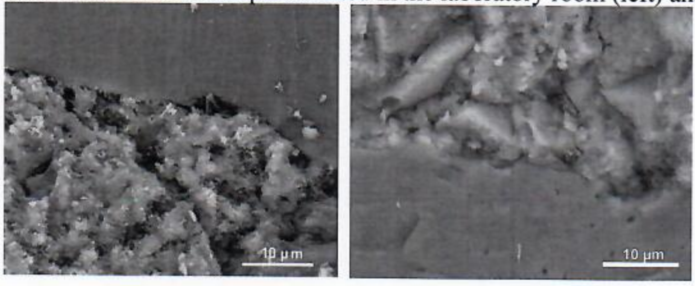

Figure 2. Contact intergrains in HcG mortar. Left) laboratory room. Right) environment.

By SEM the contact between grains of the outer zone indicates less compaction, with spongy and cracked areas that are not detected in the inner zone of the OPC. Phase recrystallizations are identified in the outer zone by an increase in the aggregates size from the contact zone and compaction of the grains (Figure 2).

3.3. Mobility within 7% HsT mortars.

As the same HcG mortar, in the siliceous HsT mortar, the sulfate-iron association was detected in the laboratory sample with two critical points. It is quite different from the behavior of the same ions in the outer sample: sulfate, Fe and Al repeat the diffusion with maximum concentrations at the end of the path. Chloride appears in both exposures and mobility of Pb, Ba and Ti is detected in the laboratory (Figure 3). Studying the contact between grains in the interior zone of the 7% HsT mortar, an intergrowth of laminar microcrystals, wrinkled lamellae and overlapping fibers is observed, producing cavities, channels and pores, resulting in a slightly larger contact intergrains zone. Spongy and cracked than in the same situation of the HcG mortar. The recrystallizations that occur in the outer zone increase the compaction in the contact between grains (Figure 4).

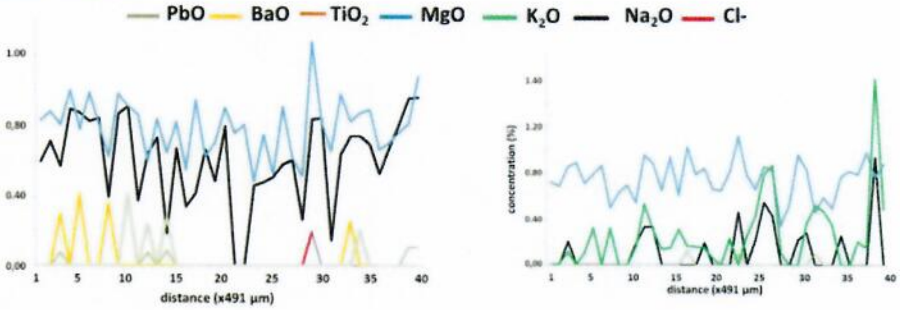

Figure 3. Mobility of ions in HsT mortar samples located in the laboratory room (left) and environment (right).

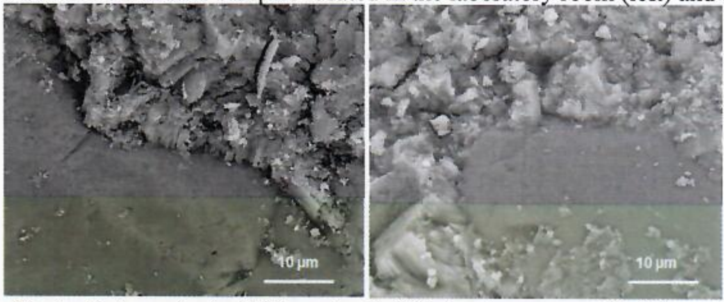

Figure 4. Contact intergrains in HsT mortar. Left) laboratory room. Right) environment.

4. Conclusions

The preparation of mortars with recycled aggregates, limestone or siliceous, facilitates the use of wastes that were once destined for landfills. Mortars made with recycled siliceous concrete are more porous than those related to limestone wastes. Exposure to a polluted environment such as the city of Madrid (Spain), retains or mobilizes polluting elements such as chlorides, Pb, Ba, being more pronounced in limestone mortars manufactured using wastes. Therefore, the fine fractions of recycled concrete may be viable as pozzolanic additions and sinks for polluting elements.

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