CHARACTERIZATION OF THE INTERFACIAL TRANSITION ZONE BETWEEN CARBONATED RECYCLED AGGREGATES AND NEW CEMENTITIOUS MATRIX: THE INTERACTIONS BETWEEN DIFFERENT CEMENTS AND CARBONATION PRODUCTS

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Abstract

In order to reduce CO_2 emissions and enhance the circularity in the cement and concrete industry, the carbonation technology applied to concrete recycling products has been widely investigated. Also, reducing the clinker content by using, for example, Ground Granulated Blast Furnace Slag (GGBS) blended cement is an important factor to achieve concrete sustainability. When applied in powder cementitious materials waste, the carbonation products are Calcium Carbonate (CC) and decarbonated silica gel, a potential supplementary cementitious material that may influence the hydration of cement and the microstructure development, by physical filling and chemical effects. When carbonation is applied to hardened concrete recycling waste, such as recycled aggregates, the above described interaction between the carbonation products and the cement occurs in the interfacial transition zone (ITZ) and the possible changes in the exiting carbonated microstructure should be considered. In this context, the focus of this investigation was the characterization of the ITZ between carbonated recycled aggregates and new cementitious matrix, with different GGBS replacement ratios, evaluating the aggregate-cement interaction and its effect on concrete's mechanical performance.

Recycled aggregate concrete was produced replacing 100% of natural aggregates (NAgg) by saturated surface dry state coarse and fine non-carbonated recycled aggregates (RA) and carbonated recycled aggregates (CRA). The carbonation was conducted in a chamber 5% CO_2 concentration, 60% relative humidity and 20°C, and the carbonation was confirmed by the pH reduction, spraying phenolphthalein solution, by the increase in density and decrease in water absorption of the carbonated aggregates. The mix design is shown on the Table 1.

Table 1. Concrete's mix design.

Identification	W/B		s/a	Binder	Coarse and Fine Aggregates
OPC	50%		48%	Ordinary Portland Cement (OPC)	Natural Aggregates (NAgg)
B30				70% OPC + 30% GGBS	Recycled Aggregates (RA)
B50				50% OPC + 50% GGBS	Carbonated Recycled Aggregates
B70				30% OPC + 70% GGBS	(CRA)

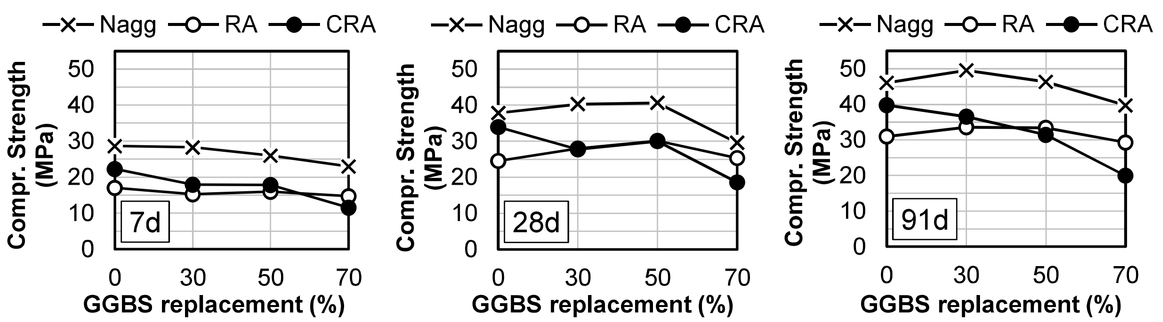

Figure 1. Influence of GGBS replacement ratio in the compressive strength (7 days, 28 days and 91 days curing) of concrete with Nagg, RA and CRA.

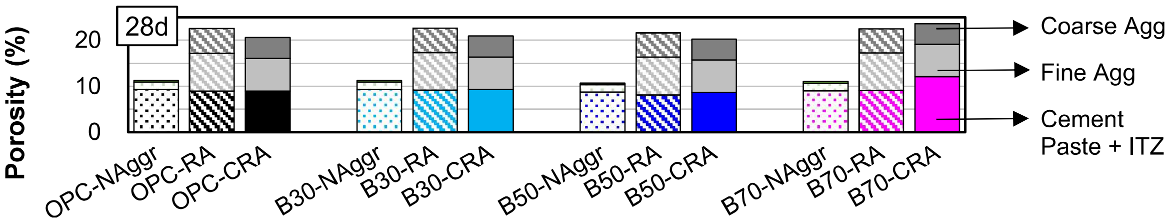

Figure 2. Porosity at 28 days of OPC and GGBS blended cement concretes, with Nagg, RA and CRA.

The compressive strength results of concrete are shown in the Figure 1. Compared to natural aggregates, the use of RA and CRA reduced the mechanical performance for all curing ages. This is caused by the attached mortar, resulting in RA and CRA having lower density and higher water absorption. As a consequence, recycled concrete's total porosity showed higher values (Figure 2), affecting the mechanical performance.

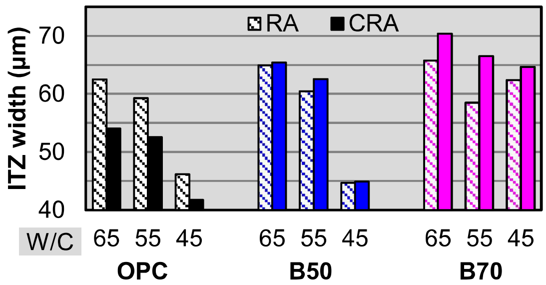

Figure 3. ITZ width between coarse RA/CRA and pastes different GGBS replacement ratios.

Comparing the effect of carbonation of aggregates on the strength, results were directly influenced by the GGBS replacement ratio. For no GGBS cement (OPC), using CRA resulted in higher strength compared to RA. But, for high GGBS replacement (B70), using CRA resulted in lower strength. So, even for the same aggregate, increasing GGBS replacement, decreased the strength of concrete with CRA, compared to RA. This suggests that carbonation treatment may have changed the surface of recycled aggregates in a way that affected negatively the aggregate-cement interaction and, consequently, the ITZ. This can be confirmed from the difference between B70-RA and B70-CRA concrete porosity's distribution (Figure 2). Even though the carbonation treatment reduced the porosity of both coarse and fine CRA, the total porosity increased for B70-CRA. This was caused by an increase in the (Cement Paste + ITZ) porosity, suggesting that aggregate-cement interaction occurred and that CC from carbonation may not be as stable as CC in natural limestone aggregate.

Then, the ITZ width between coarse RA or CRA (from demolished concrete with W/C of 60%, 55% and 45%) and cement pastes with 0%, 50% and 70% GGBS replacement (OPC, B50 and B70, respectively) was calculated, considering linear hardness measurements smaller than 80 HV, from Vickers Hardness test (Figure 3). High W/C of the demolished concrete increased the ITZ width because of the initial higher porosity of the recycled aggregates, but the changes in ITZ width with carbonation treatment was largely influenced by the GGBS content the new cementitious matrix. There was a decrease in the ITZ width between all 3 types of CRA and the OPC paste. However, an increase in the ITZ width between all 3 types of CRA and the B70 paste was observed. For CRA and B50 pastes, the ITZ width showed an intermediate behavior. These differences in ITZ depending on the cement type, even for the same aggregate, are an evidence of aggregate-cement chemical interaction, i.e. the interaction between CC and silica gel from carbonation treatment in the CRA's surface and high GGBS replacement cement pastes, which may have resulted in increasing the ITZ width. This explains the porosity increase (Figure 2) and the decrease in compressive strength (Figure 1), as the ITZ is considered the weakest part of concrete, where microcracks often initiate and propagate.

Keywords
Accelerated carbonation; recycled aggregate; ground granulated blast furnace slag; interfacial transition zone; aggregate-cement interaction