Microsc. Microanal. 19 (Suppl 4), 2013

doi:10.1017/S1431927613001359

Microstructure of concrete prepared with construction recycled aggregates

L. Evangelista*,**, M. Guedes***,****, A. C. Ferro***,***** and J. de Brito*,******

*ICIST, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
** Department of Civil Engineering, Instituto Superior de Engenharia de Lisboa, R. Conselheiro Emídio Navarro, 1, 1959-001 Lisbon, Portugal
***ICEMS, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
****Department of Mechanical Engineering, Escola Superior de Tecnologia de Setúbal, Instituto Politécnico de Setúbal, 2910-761 Setúbal, Portugal
*****Department of Mechanical Engineering, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
******Department of Civil Engineering, Architecture and Georesources, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

Conservation of natural resources, shortage of waste land and the high cost associated to treatment prior to disposal are driving growing interest in the recycling of construction and demolition waste materials (CDW). A challenging application for recycled CDW is the replacement of natural aggregates in the production of structural concrete. In the past few years several studies have examined the viability of this substitution. Although recycled aggregates are mostly heterogeneous, less dense and more porous than natural aggregates [1], satisfactory results have been attained by several authors regarding concrete workability, mechanical properties and durability. However, a systematic microstructural characterization of recycled aggregate concrete is still unaccomplished.

In this context, the use of fine recycled concrete aggregates to replace natural fine aggregates in the production of structural concrete was tested, and attained microstructures are reported. The recycled aggregates were obtained from a standard concrete, produced and crushed under laboratorial conditions [2], thus allowing full control of concrete's composition and setting. The used raw materials were natural aggregate (sand), recycled aggregates and Type 1 Portland cement. The substitution extent in the mixtures was 0, 10, 50 and 100 wt%; hydration was stopped at the ages of 9 h, 24 h, 96 h and 28 days. Microscopy study of the different mixtures enlightened the effect of the incorporation of recycled aggregates upon the formation and morphology of the different concrete hydration products. In this work, FEG-SEM (coupled with EDS microanalysis) was used on polished cross sections and fracture surfaces, to study the new mixtures. Focus was placed on the interfacial transition zone (ITZ) between cement matrix and aggregate.

The natural aggregate-cement interfacial zone exhibits typical microstructural features of the ITZ of a normal strength concrete. After 28 days a large amount of well-crystallised C-S-H (and a small amount of poorly crystalline fibres) is present at the interface, together with CH deposits. Grains of unreacted clinker components (C_2S, C_3S, $Ca_2(Al,Fe)$, C_3A) were also identified; ettringite crystals are barely present, even at the earlier hydration times. The ITZ is highly porous. Independently of the setting time, fracture takes place preferably along the surface between paste and aggregate, attesting the relatively loose nature of the interface. The structure of ITZ with recycled aggregates (Figure 1) is consistent with that observed in the reference natural concrete. Also, calculation based on EDS results rendered a lime to silica ratio (C/S) of 1.46 ± 0.15, consistent with the typical 1.2-2.3 range [3]. However, there are representative microstructural features that may contribute to variation of mechanical properties. Ettringite and plate-like CH hydrates are much more abundant, even at higher setting times. Overall porosity in the ITZ increases with the aggregate substitution extent; however maximum pore size decreases from approximately 30 μm for 0% substitution to 16 μm for 100 % substitution, as shown by image analysis results. In fresh natural concrete a water film forms around the aggregates, which is gradually replaced by the growing amount of hydration products [1]. In recycled aggregates, active silica in residual cementitious materials reacts with the fresh cement hydration products. The secondary reaction products gradually fill the region, partially covering the recycled aggregates pore structure and creating additional interfacial bonding effects (Figure 2). In good agreement, it was observed that in substituted concretes fracture preferably takes place throughout the paste rather than throughout the contact surface.

Concretes prepared with recycled aggregates exhibit typical microstructural features of the ITZ in normal strength concrete. Although porosity at the ITZ is affected by the extent of aggregate replacement, the interfacial bond is apparently stronger when recycled aggregates are used. This envisages an opportunity window for the development of increased strength Portland cement concretes.

References

1. Poon C.S. *et al*., Constr. Build. Mater., 18:461-468, 2004.
2. Evangelista L. and deBrito J., Cem. Concr. Compos., 29:397-401, 2007.
3. Medina C. *et al*., Constr. Build. Mater., 31:112-118, 2012.

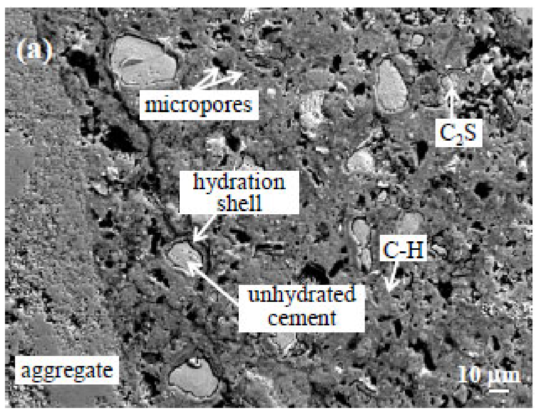

Figure 1. BEI of polished cross-section at the ITZ for concrete with 100% substitution (28 days).

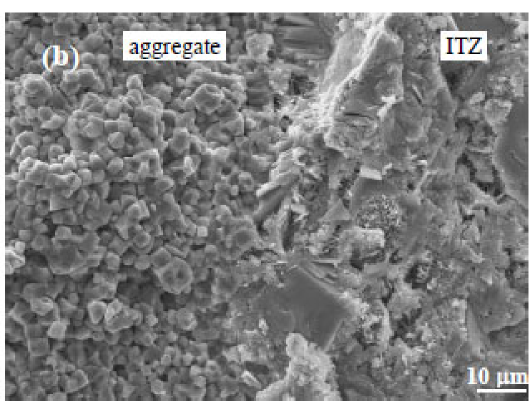

Figure 2. SEI showing interfacial bonding at the ITZ in concrete with 50% substitution (28 days).

https://doi.org/10.1017/S1431927613001359 Published online by Cambridge University Press