Self-Compacting Concrete with Recycled Concrete Aggregate: Resistance against Aggressive External Agents

Víctor Revilla-Cuesta¹, Marta Skaf², Aratz García-Llona³, Ignacio Piñero³, Juan M. Manso¹ and Vanesa Ortega-López¹

¹ Department of Civil Engineering, Higher Polytechnic School, University of Burgos, Villadiego St, 09001 Burgos, Spain, {vrevilla, jmmanso, vortega}@ubu.es. Víctor Revilla-Cuesta: Corresponding author
² Department of Construction, Higher Polytechnic School, University of Burgos, Villadiego St, 09001 Burgos, Spain, {mskaf}@ubu.es
³ Fundación TECNALIA Research & Innovation. Parque Tecnológico de Bizkaia. C/Geldo, ed.700, E48160 Derio-Bizkaia, Spain, {aratz.garcia, ignacio.pinero}@tecnalia.com

Keywords: Self-Compacting Concrete, Recycled Concrete Aggregate, Freeze/Thaw Test, Moist/Dry Test, Sulphate Attack Test.

1 Introduction

The construction sector is a major contributor to one of the most important environmental problems: the lack of natural resources (Sandanayake et al., 2019), standing out the high consumption of aggregates. For example, according to National Association of Aggregate Manufacturers of Spain (ANEFA), in 2017, 112 million tons of aggregates were consumed in Spain (ANEFA, 2018). Aggregate substitution in several materials, including concrete, by different types of waste, such as Recycled Concrete Aggregate (RCA), is an area of study that has opened several research lines (RCA) (Safiuddin et al., 2013).

RCA, especially the fine fraction, decreases compressive strength (Evangelista et al., 2014). Durability is also affected, because of the high porosity of the attached mortar (Guo et al., 2018). Self-Compacting Concrete (SCC) has a lower porosity due to its high flowability.

In line with the above, the durability of an SCC design consisting of 100% coarse RCA and 50% by volume of fine RCA is evaluated in this research. This concrete underwent three tests: behavior during freeze/thaw and moist/dry cycles, and resistance to sulphate attack.

2 Mix-design. Mechanical and In-Fresh State Studies

The dosage was: 296 kg/m³ of cement, 122 kg/m³ of filler, 183 kg/m³ of water, 522 kg/m³ of coarse RCA (density of 2.42 kg/dm³ and 24h water absorption of 6.25%), 570 kg/m³ of fine RCA (density of 2.37 kg/dm³ and 24h water absorption of 7.36%), 343 kg/m³ of siliceous sand 0/4 mm, 215 kg/m³ of limestone sand 0/1.2 mm, 2.20 kg/m³ of admixture 1 (viscosity adjuster) and 4.35 kg/m³ of admixture 2 (superplasticizer). The compressive strength was 28 MPa at 1 day, 38.3 MPa at 7 days and 45.6 MPa at 28 days. Table 1 shows the performance in fresh state.

| T₅₀₀ (s) | Maximum diameter (mm) | Viscosity in V-Funnel test (s) | Passing ability in L-box test | Sieve segregation (%) |
|----------|------------------------|-------------------------------|-------------------------------|-----------------------|
| 4        | 720 (SF2 class)        | 7 (VF1 class)                 | 0.97 (PA1 class)              | 0.41 (SR2 class)      |

Table 1. Results of in-fresh state studies. SCC class (EFNARC, 2002).
3 Durability Tests

The decrease in compressive strength was very similar in both the moist/dry test and the freeze/thaw test. It appears that the large number of micro voids in the moist/dry test and the high loss of mass in the freeze/thaw test had the same effect. Sulphate attack test was less damaging to SCC, which could be due to the very low number of small-sized surface pores in the hardened state. Hence, the penetration of higher density solutions within the concrete was less likely. Table 2 shows all results.

Table 2. Results of the durability tests.

| Parameter/Test                      | Freeze/thaw | Moist/dry | Sulphate attack |
|-------------------------------------|-------------|-----------|-----------------|
| Number of specimens tested          | 4           | 3         | 2               |
| Loss of mass (%)                    | -14.23      | -2.40     | -0.48           |
| Side expansion (%)                  | -           | -         | +0.02           |
| UPV variation (%)                   | -14.67      | -29.87    | -16.62          |
| Compressive strength variation (%)  | -34.32      | -29.93    | -19.01          |

4 Conclusions

Correct dosage design of an SCC with large amounts of RCA will result in high flowability in the fresh state and a high compressive strength. Durability tests showed that external agents adversely affect the properties of the concrete, although the affections are not critical. Therefore, a good design will mean that the SCC with RCA can be used in environments with aggressive external agents. In addition, the greater the ease with which the external agent penetrates within the concrete, the worse the effect of those agents on the concrete.

ORCID

Victor Revilla-Cuesta: http://orcid.org/0000-0003-3337-6250
Marta Skaf: http://orcid.org/0000-0001-7205-2692
Aratz García-Llona: http://orcid.org/0000-0002-8202-1424
Ignacio Piñero: http://orcid.org/0000-0003-1987-1677
Juan M. Manso: http://orcid.org/0000-0003-4964-5128
Vanesa Ortega-López: http://orcid.org/0000-0003-0212-355x

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