High performance self-compacting concrete with recycled aggregates from the precast industry

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High performance self-compacting concrete with recycled aggregates from the precast industry

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1. Introduction

In this short communication, we present the results of an experimental campaign whose final objective was to produce high performance self-compacting concrete (HPSCC) using recycled aggregates (RA) from the precast industry (PI). This work intended to evaluate the potential of self-compacting concrete with RA to achieve similar performance as high performance concrete. The results of the tests carried out on six concrete mixes are presented, wherein the first one corresponds to a mix using natural aggregate (NA) only (100% NA) and the remaining five mixes in which the percentage of fine recycled aggregate (FRA) and coarse recycled aggregate (CRA) in the concrete composition varies, namely: 1st FRA/CRA%: 25/25% (25% RA); 2nd FRA/CRA %: 50/50% (50% RA); 3rd FRA/CRA %: 100/100% (100% RA); 4th FRA/CRA %: 0/100% (100% CRA); 5th FRA/CRA %: 100/0% (100% CRA). The cement replacement percentage with mineral additions was kept constant in all the mixes and included 5% of limestone filler (LF) and 30% of fly ash (FA) (instead of cement). The amount of silica fume (SF) and cement (C) was also kept constant in all mixes: 10% SF (relative to the cement weight) and 450 kg/m³ of C. The a/c ratio of all the mixes was 0.44. A value of the ratio, in absolute volume, between the total amount of fine material (cement and additions) and fine aggregates in the mixes (Vp/Vs) was set. According to the results obtained by Silva et al. (2011), a value Vp/Vs=0.80 was considered.

2. Material and methods

The fine natural aggregate used in all the mixes was silica sand, in two sizes: fine sand (0-2 mm) and coarse sand (0-4 mm). Two types of limestone CNA were used: medium gravel (Dmax = 11.2 mm) and coarse gravel (Dmax = 22.4 mm). The RA came from crushed precast concrete elements of 65 MPa class strength. Type I cement of class 52.5R, limestone filler and fly ash (used as a partial replacement for the cement) were used in ternary mixes. A high-performance superplasticizer was used as admixture.

3. Results and conclusions

Table 1 shows a summary of the results obtained, where a negative sign corresponds to a decrease and a positive sign to an increase in the value of the property under analysis. The
comparisons are made in relation to the 100% NA mix. The results in Table 1 show that the 25% RA mix performs best, with losses of less than 10%. The mixes with 50% RA and 100% CRA present similar performances even though the first one tends to have worse results than the second one. The 100% RA mix shows the highest losses. The registered differences may be justified by the nature of the CRA and the water absorbed by them.

Table 1 - Hardened-state properties results overview at 28 days

| Hardened-state properties | Mix and respective increase/decrease compared to the reference HPSCC (100%NA) |
|---------------------------|--------------------------------------------------------------------------------|
|                           | 25% RA  | 50% RA  | 100% RA | 100% CRA | 100% FRA |
| Compressive strength in cubes | -1%     | -3%     | -8%     | -2%      | -5%      |
| Splitting tensile strength | -10%    | -23%    | -32%    | -19%     | -28%     |
| Modulus of elasticity      | -5%     | -12%    | -26%    | -11%     | -21%     |
| Ultrasonic pulse velocity  | -1%     | -4%     | -8%     | -2%      | -6%      |
| Abrasion resistance        | +6%     | +13%    | +39%    | +10%     | +36%     |
| Shrinkage                  | +3%     | +13%    | +23%    | +13%     | +20%     |
| Creep                      | +20%    | +34%    | +97%    | +30%     | +84%     |

The need of correction of the mixing water volume due to the high absorption by the RA means that, in particular CRA can retain, during the initial stage of mixing, large quantities of water. This water, which is not used for workability nor for any hydration process in the initial stage, is available to contribute to the later reaction of FA with calcium oxide or calcium hydroxide (products from the cement hydration). The substitution of NA with RA causes a decrease of the hardened-state properties (namely compressive strength and splitting tensile strength). This is explained by the poor quality of RA, which has its origin in the adhered mortar and is responsible for increasing the porosity and cracking of the aggregates, making connections in the transition zone between the RA and the new binder weaker. At 28 days, decreases of 1% to 8% in the compression strength were recorded and from 10% to 32% in the splitting tensile strength.

According to the NP EN 206-1 (2007) standard classification, the 100% RA mix belongs to the C50/60 class resistance and the remaining mixes to the above class: C65/67. Thus, according to the standard mentioned, all concrete produced can be classified as high performance. A decrease in the modulus of elasticity is observed with RA increase, which is explained by the lower stiffness of RA (compared to NA), given the presence of old mortar adhered in RA and also to the lower deformability of the binder. At 28 days, there is a reduction of 5% to 26% in the modulus of elasticity. The lower stiffness of RA, compared to NA, decreases the overall stiffness of the concrete and, therefore, increases the shrinkage and creep behaviour. There is also an increase in shrinkage and creep at 91 days larger than the one registered at 7 days due to the internal healing phenomenon triggered by RA. At 28 days, reductions of less than 23% of shrinkage occur.

4. References

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NP EN 206-1, Concrete, Part 1 (2007) Specification, performance, production and conformity, Lisbon, Portugal, IPQ.