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Cementitious compositions obtained with recycled aggregates and micro/nanosilica admixtures

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Introduction

Figures 1a,b: Images from obtaining and testing compression mortars

A way to reduce the negative impact on the environment is the use of recycled concrete aggregates (RCA) in order to recover construction waste (Salgado, 2022), according to EU Directive 2018/851. Additionally, hydraulically active materials (Snellings, 2016), as a partial substitute for cement in mortars and concretes, can also be used. One of the most effective active hydraulic admixtures is microsilica and more recently, nanosilica, (Li, 2017; Abhilash, 2021).

Figures 2a,b: Images from the compression test of concrete samples and freeze-thaw by exfoliation

The research focused on two types of cementitious systems made with recycled aggregates and micro/nanosilica:

- a special mortar composition used for encapsulating low level radioactive waste with constant water/cementitious materials ratio, fig.1a,b;
- a composition of structural concrete, class C30/37, with the combination of exposure classes XC4+XF1 and W/CM ratio 0.47, fig.2a,b.

Aims

The present study aims to evaluate the effect of micro and nanosilica, as well as mixtures of the two, on the properties of some cementitious compositions, made with recycled concrete aggregate. The compressive strength of mortars and concretes was evaluated. The durability of the concrete was assessed by the freeze-thaw behavior.

Materials & Methods

The mortar was made with 100% recycled aggregate. The partial replacement of cement was done progressively, in the case of the mortar composition, with microsilica (3, 6, 9, 12, 15% wt.), nanosilica (0.75, 1.5, 2.25% wt.), respectively mixtures of two. It was used: CEM II B-M 42.5R, SikaFume HR/TU type microsilica (MS), Levasil type colloidal nanosilica (CB, 50% nanosilica content), additives. In the case of concrete (noted as R30 and R40), 30% respectively 40% recycled aggregate was used for 4-8 and 8-16 sorts. The control composition (M) was made 100% with natural aggregate.

Results & Discussion

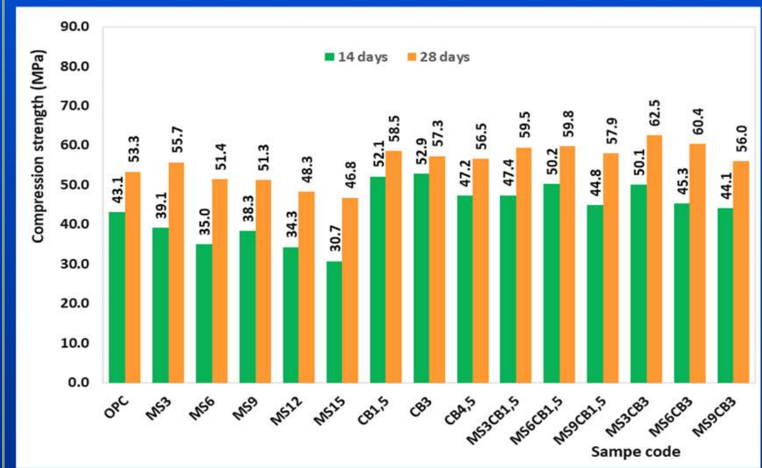

Figure 3: Compressive strength of mortars with micro/nanosilica

Figure 3 shows the compressive strength values, obtained at 14 and 28 days, for all investigated mortar compositions. From the data presented, the following trends are highlighted:

- for the compositions with microsilica, the best results, after 28 days of hardening, were obtained at a content of 3% microsilica, over 10% microsilica the compression strength decreasing significantly;
- in the case of samples with colloidal nanosilica, the compressive strengths are superior to the control sample (OPC) and the samples with microsilica, for all mortar compositions analyzed (CB1.5, CB3, CB4.5);
- if micro and nanosilica are used simultaneously, a synergistic effect of silica is observed which makes the compressive strengths for those samples higher than those corresponding to samples with only nanosilica; the best results were obtained using 3%, respectively 6% microsilica in combination with 1.5% nanosilica (3% CB8), compositions MS3CB3 and MS6CB3;
- the greater difference between the compressive strength values, at 14 days compared to 28 days, for samples with microsilica compared to those with nanosilica, indicates the increased reaction speed of nanosilica determined by the very high specific surface area.

The RS30 and RS40 concrete compositions were obtained by replacing the cement with 3% microsilica and 1.5% nanosilica (3% Cembinder8), the optimal mixture of micro/nanosilica from the point of view of mechanical resistance on mortars.

Table 1 and figure 4 highlight the results obtained on concrete:

- the decrease of the slump class for the concretes made with recycled aggregates (at the same W/C ratio), compared to the control concrete (M); better cohesiveness and homogeneity of concretes with micro and nanosilica content;
- due to the recycled aggregate being more porous than the natural aggregate, the compressive strength decreases for compositions R30 and R40 compared to the control composition (M); the silica content for RS30 and RS40 improves the compressive strength compared to R30 and R40, and even compared to the control composition (M);
- the increase in structural compactness given by the silica content increases the freeze-thaw resistance, respectively the durability of concretes with recycled aggregates and silica.

Table 1 Concrete characteristics

Characteristics	Concrete,				
	M	R30	RS30	R40	RS40
Slump, mm	160	0	5	0	0
Compressive strength, MPa	53.7	49.1	56.9	51.4	54.4
Freeze-thaw resistance, Kg/m^2	-	0.26	0.20	0.17	0.15

Figure 4: The relative variation of the compressive strength for concrete samples.

Conclusions

The use of a mixture of 3% microsilica and 1.5% nanosilica, as a substitute for cement, proved optimal in terms of compressive strength, in the case of special mortars made with recycled aggregates. The same combination of micro and nanosilica improved the durability of some concretes in which the natural aggregate was partially replaced by recycled aggregates.

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