Cementitious compositions obtained with recycled aggregates and micro/nanosilica admixtures

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Cement mortars and concretes are some of the most used construction materials in the world, global cement production being expected to grow to approx. 5 billion tons, until 2030, (Danish, 2019). But, cement is an energy intensive material, the cement industry being responsible for cca. 7% of the world's CO_2 emissions, (Tiseo, 2020). In addition to CO_2 emissions, SO_3 and NOx emissions are also added, which can cause the greenhouse effect and acid rain, (Valipour, 2014).

Also, natural aggregates represent non-renewable resources, exhaustible, which must be used efficiently. The construction industry is a major consumer of natural resources, with global natural aggregate production expected to rise to approximately 60 billion tons in 2030, (Kim, 2022; de Andrade Salgado, 2022).

A way to reduce the negative impact on the environment is the use of additional hydraulically active materials (Snellings, 2016), as a partial substitute for cement in mortars and concretes and/or the use of recycled concrete aggregates (RCA) for the recovery of construction waste, according to EU Directive 2018/851. One of the most effective active hydraulic admixtures is microsilica and more recently, with the technological development on a nanometric scale, nanosilica, (Li, 2017; Abhilash, 2021).

Studies carried out in recent years have shown that the introduction of SiO_2 nanoparticles into cement matrix improves the properties, even compared to microsilica, (Li, 2017). This is due to the very small size of the nanosilica particles (<100nm) and the very large specific surface, which helps to accelerate cement hydration and acts as a nucleating agent to generate even more calcium hydrosilicate which densifies and compacts the structure, (Abhilash, 2021).

The cementitious compositions containing recycled concrete aggregates (RCA) present, in generally, inferior properties compared to those obtained with natural aggregates. Depending on the degree of replacement of natural aggregate, decreases the workability of mortars and concretes with RAC, decrease mechanical resistances and increase drying shrinkage; all being determined, in particular, by the presence to the old mortar attached to the original aggregate from the RAC, which makes its porosity high and the mixture of components to require more water for preparation, (Kubissaa, 2015.

The present study aims to use micro and nanosilica for increase the performance of some mortars and concretes obtained with RCA.

The research focused on two types of cementitious systems:

- a special mortar composition used for encapsulating Low Level radioactive Waste (LLW);
- a composition of structural concrete, class C30/37, with the combination of exposure classes XC4+XF1 and settlement class S4.

The mortar was made with 100% recycled aggregate, 0-5 mm sort and in the case of concrete, 30% recycled aggregate was used for 4-8 and 8-16 sorts, according to EN 206, Annex E. The recycled aggregate was obtained from a specially made concrete for this study, which after 28 days was crushed with the help of a Retsch jaw crusher and further separated by sieving on granulometric sorters.

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 micro and nanosilica. The optimal combination of silica, from the point of view of mechanical resistance, was later used also in the case of the concrete composition.

Mortar used for embedding low level concrete waste (LLW) must meet specifications applicable to LLW waste. The technical criteria for LLW waste were taken as targets to be achieved, as follows:

- fluidity: 16 ÷ 50 s flow time through a standardized flow cone (p-cone time), given by the American Standard of Testing Materials C939;
- maintaining the fluidity of the mortar: more than 60 min without separating the constituents or without bleeding;

- compressive strength of the mortar: minimum 30 MPa, after 28 days;

Superplasticizer additives and viscosity modifiers were used in the case of mortars and superplasticizer additives for concrete. For all the additives used, compatibility tests were done with the type of cement used, respectively with cement and micro/nanosilica.

Images from obtaining mortar and concrete samples with micro and/or nanosilica are shown in fig.1.

Fig.1 Mortar and concrete samples in different stages.

For the chosen cementitious compositions, the influence of micro and/or nanosilica on the properties in the fresh state (workability, rheological characteristics) and hardened state (mechanical resistance, water absorption, freeze-thaw resistance, etc.) is highlighted.

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