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The impact of nanosilica and waste glass cullet on selected physico-mechanical parameters in cement mortars

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ABSTRACT

1. Introduction

The disposal of waste glass is a challenge that must be faced to protect the environment. When taken into account, achievements in nanomaterial technology make it feasible to obtain cementitious composites with comparable or even more favorable parameters in relation to those produced by traditional methods. These two aspects became the inspiration for this experimental research on the impact of nanosilica and waste glass cullets on selected physico-mechanical parameters of cement mortars.

2. Materials and tests

Three types of cement mortars were prepared and designated as WG (mortars with waste glass), RWG (mortars with natural sand and waste glass) and R (control mortars with natural sand) containing respectively 100%, 50% and 0% substitution (by volume) of natural sand with waste glass aggregate. Glass grains and natural aggregate used in the study are presented in Figure 1 and 2. The difference in the shape of natural grains (oval grains) and waste glass grains obtained from milling process (grains elongated and needle-shaped) should be noted. The grading of WG has been prepared in accordance with EN 196-1 requirements.

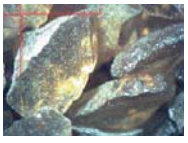

Fig.1. The glass cullet fraction 1.6 -2.0; 25x magnification.

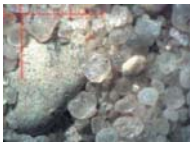

Fig. 2. The natural sand fraction; 25x magnification.

The prepared mortars were modified with nanosilica in the amount of 0%, 1% and 3% by the weight of cement, respectively. The commercially available amorphous nanosilica suspension (NS) containing 20 wt% of solid material, cement CEM I 42.5R and tap water were used for that purpose. In order to obtain a reasonable consistency of mortars, polycarboxylate ether (PCE) superplasticizer was used. Table 1 presents the composition of all mixtures. Fresh mortar was poured into oiled molds for sample formation, and cured in a standard water bath at 20 °C ± 2 °C. Flexural and compressive strength tests were performed after 7, 28 and 365 days of curing. In the freeze-thaw durability test, half of the samples served as comparative samples and were stored in a climatic chamber. The remaining samples were subjected to 100 freezing (4h) and thawing cycles (4h). Drying shrinkage was tested in the environment of different relative humidity, namely the first group was cured in a climate chamber at 20 ° C ± 1 and

RH = 50% ± 2% during 365 days, while the second group was placed in a water bath above water at 20 ° C ± 1 and RH = 95% for 120 days. A non-stationary method using the ISOMET 2104 apparatus was used to measure thermal conductivity. The thermal conductivity of cement mortar samples was determined in wet and dry state. The adhesion of mortars to the ceramic substrate was determined by the pull-off method, using solid bricks. The abrasion test was carried out on a Böhme disc. The samples sized in 40 × 40 × 160 mm were used to measure humidity and water absorption,.

Table 1. Mixture compositions

Components content		Sample designation								
		WG0	**WG1**	**WG3**	**RWG0**	**RWG1**	**RWG3**	**R0**	**R1**	**R3**
Waste glass content	[%]	100	100	100	50	50	50	-	-	-
River sand content		-	-	-	50	50	50	100	100	100
Cement	[kg/m^3]	519	519	519	519	519	519	519	519	519
Water		257	239	197	257	239	197	257	239	197
Nanosilica		-	26	78	-	26	78	-	26	78
Superplasticizer		3.6	3.6	3.6	1.6	1.6	1.6	1.6	1.6	1.6

3. Results and discussion

The results analysis allowed to draw following conclusions:

- Total replacement of natural aggregate with waste glass has a beneficial effect on the mechanical properties of cement mortar.
- Nanosilica improves physico-mechanical properties of cement mortars.
- Wasted glass aggregate and nanosilica significantly improve the resistance to the freezing and thawing of cement mortars.
- The value of drying shrinkage increases proportionally with the nanosilica content in mortars.
- Waste glass aggregate affects the increase of drying shrinkage.
- Seasoning above water confirms a significant reduction in the volume changes of mortars as a result of surface-wasting water.
- Waste glass aggregate combined with nanosilica reduces thermal conductivity.
- The adhesion to the ceramic cement mortar substrate decreases with the increase of nanosilica content.
- Nanosilica admixture improves the abrasion resistance of cement mortars.
- Elongated and needle-shaped characteristics of waste glass cause the consistency decrement in cement mortars.

Obtained results have proven the grounds for using waste glass in the building materials industry, which is in accordance with the expectations issued in Regulation (EU) No 305/2011 of the European Parliament and the Council on 9th March 2011, where it was established that construction products launched to the EU market should be consistent with the principles of sustainable construction.

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