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IMPACT OF GLASS AND CERAMIC WASTE ON SELECTED PROPERTIES OF MATERIALS WITH A CEMENT

The article presents the impact of selected waste materials (usable ceramics, sanitary ceramics, CRT glass cullet) on the physical and mechanical properties of cement-based materials (cement mortars). The samples of cement mortars made were 10, 20 and 30% addition of waste material. Physical and mechanical properties of modified cement mortars were compared with standard mortar. The highest compressive strength obtained mortar with the addition of usable and sanitary ceramics in the amount of 30%. The mortar was also characterized by the lowest decreases in compressive strength after frost resistance tests. The use of 30% sanitary ceramics resulted a compressive strength drop of 3.5% compared to 18% for the standard mortar. The absorbability of all samples differed slightly.

Keywords: cement mortars, mechanical properties, utilitarian ceramics, sanitary ceramics, CRT glass

1. Introduction

The development of industry and economy causes an increase in post-production and post-use waste. Many of the generated waste creates difficulties during processing, while others do not apply and are completely deposited in landfills. This results in a threat to the natural environment and obliges the public to look for new pro-ecological technologies for their management.

One of the sectors that produces large amounts of waste materials is construction. This sector, and especially the construction materials sector, also offers opportunities for managing different types of post-use and post-production waste emerging in other sectors of the economy (dust and slag from the steel industry, waste from the glass industry, waste from polymer processing). On the laboratory scale, attempts are made to use construction waste materials such as demolition materials [1, 2], ceramic hollow bricks [3, 4], sanitary ceramics [5–8],

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fibers and glass waste [9–11], rubber waste [12], polymeric materials [13], cork [14], rice husks [15, 16], or ashes from the co-firing of biomass [17, 18]. The use of waste requires each time to determine their physicochemical properties and physical and mechanical properties of the newly created building materials. This paper attempts to determine the impact of selected ceramic and glass waste on the strength of cement mortars.

2. Research procedure

The research used utility ceramics (post-production waste of pots and covers), sanitary ceramics (used sinks and toilet seats) and cracked glass CRT (glass from the screen and a cone of used monitors). and crushed to a fraction of 0.0–2.0 mm using a jaw crusher and disintegrator (Fig. 1). Fragmentation the waste after crushing had sharp edges, characteristic for broken aggregate. The chemical composition of the tested materials determined using X-ray fluorescence presented Table 1.

Fig. 1. Shredded: a) utilitarian ceramics waste, b) sanitary ceramics waste, c) CRT glass

Cement mortar samples were made using Portland cement CEM I 42.5 R (Cemex), standard sand (Kwarcmix) and tap water with pH 7.7 and Cl^{-} = 31 mg/dm^3 and NO_3^{-} = 37 mg/dm^3 from the intake Czestochowa. The composition of the tested cement mortars is shown in Table 2. Standard mortar (PK) and mortar samples were made, in which 10, 20 and 30% of the cement mass was replaced with functional ceramics (CU1 – CU3), sanitary ceramics (CS1 – CS3) or glass cullet (SS1 – SS3). The waste was used as a substitute for standard sand.

Table 1. Chemical composition of the investigated waste

Compound	Chemical composition, %		
	Usable ceramics	**Sanitary ceramics**	**CRT cullet**
SiO_2	58.2	69.8	60.4
CaO	6.9	0.5	0.8
K_2O	2.0	2.7	4.0
Al_2O_3	19.3	22.4	1.5
Na_2O	1.3	1.6	5.6
MnO	1.0	0.6	0.6
PbO	-	-	11.6
SrO	-	-	5.2
Inne	11.3	2.4	10.3

Table 2. Composition of cement mortars – mixing ratios

Composition	Series									
	PK	**CU1**	**CU2**	**CU3**	**CS1**	**CS2**	**CS3**	**SS1**	**SS2**	**SS3**
Cement, g	450	450	450	450	450	450	450	450	450	450
Water, cm^3	225	225	225	225	225	225	225	225	225	225
Standard sand, g	1,350	1,305	1,260	1,215	1,305	1,260	1,215	1,305	1,260	1,215
Usable ceramics, g	-	45	90	135	-	-	-	-	-	-
Sanitary ceramics, g	-	-	-	-	45	90	135	-	-	-
CRT cullet, g	-	-	-	-	-	-	-	45	90	135
Waste, %	0	10	20	30	10	20	30	10	20	30

The beams with dimensions 40×40×160 mm were made in accordance with PN EN 196-1. The products were arranged in forms after making the mixture, compacted and covered with a glass plate and left for 24 hours. After this time they were demoulded and put into water at 20°C. After 28 days, compressive strength , frost resistance and water absorption tests were performed on the bars. The compressive strength test (average of 6 samples) was carried out on the tails halves with an accuracy of 0.1 MPa on a Tonitechnic hydraulic press and the compressive strength was determined with such accuracy. Measurements of compressive strength after frost resistance tests (average of 6 samples) were performed after 25 cycles of freezing and thawing in the Toropol machine.

3. Methodology and test results

Samples of cement mortars were subjected to compressive strength tests after 28 days. The control sample (PK) obtained a compressive strength of

47.4 MPa (Fig. 2). With the increase in the addition of utilitarian ceramics, an increase in the strength value of the beams was observed by 1–4% in comparison with the control beams. The highest compressive strength obtained samples containing 30% of utilitarian ceramics. The use of sanitary ceramics resulted in greater disparities between the three series of mortars. Compressive strength increased as the amount of additive grew (0.5% to 8.5%), relative to the standard mortar. An addition to the cement mortar CRT cullet increased the average compressive strength only for the series with the addition of 10% waste.

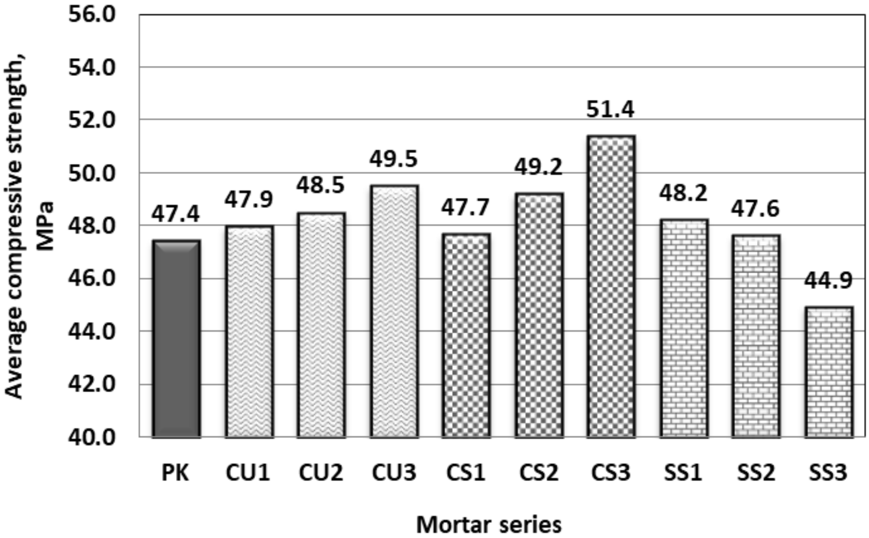

Fig. 2. Average compressive strength of investigated cement mortars

In the next stage of the tests, the frost resistance of the beams was determined in accordance with the PN-88/B-06250 standard. Samples of 28 days in water were weighed and subjected to 25 freezing cycles at -18°C ± 2°C for 4 hours and thawing in water at +18°C ± 2°C for 4 hours. Then they were weighed again and subjected to compressive strength tests. The obtained results were presented as a percentage decrease in compressive strength after frost resistance tests compared to witness samples that were not frozen. The decrease in compressive strength after freezing tests of standard mortar amounted to 18.2% (Fig. 3). Samples with sanitary ceramics obtained the smallest drop in resistance to dripping in abrasion with samples of waste household ceramics or CRT glass. Samples with sanitary ceramics had the smallest drop in compressive strength in comparison to samples of consumer ceramic waste or CRT glass. The lowest decrease in compressive strength after frost resistance tests was observed in bars with the addition of 30% of utilitarian and sanitary ceramics, which amounted to 5.5% and 3.5%. The mortar beams contain the glass cullet and have slightly less dips in the resistance to dripping than the standard mortar.

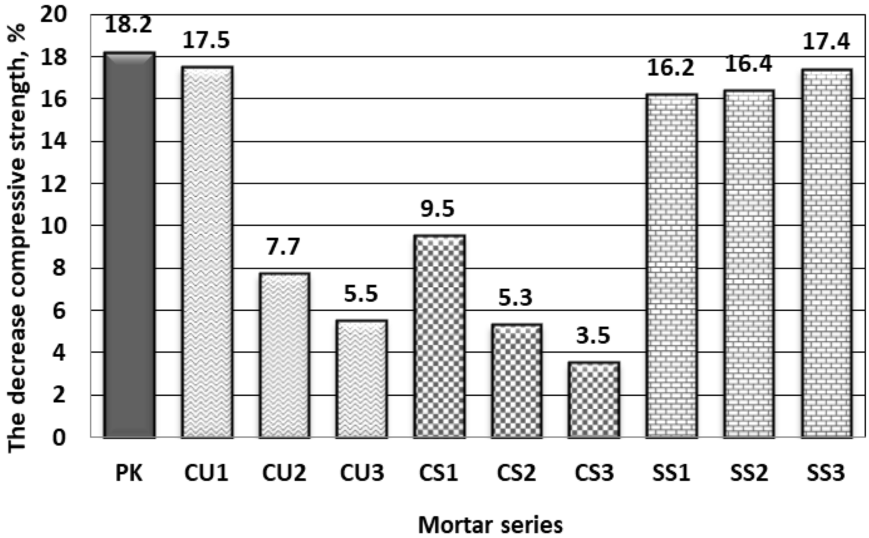

Fig. 3. Decrease compressive strength of the cement mortars after frost resistance tests

Another test carried out was absorbability of cement mortars. Samples after 28 days of being in water to obtain a constant weight, were dried at 105°C to obtain differences between weighings not exceeding 0.1%. The standard mortar has achieved an absorption of 8.5% (Fig. 4). The absorbability of the other cement mortars made was only slightly different. It can be noticed that the increasing amount of each of the additives increased the absorbability of cement mortar beams.

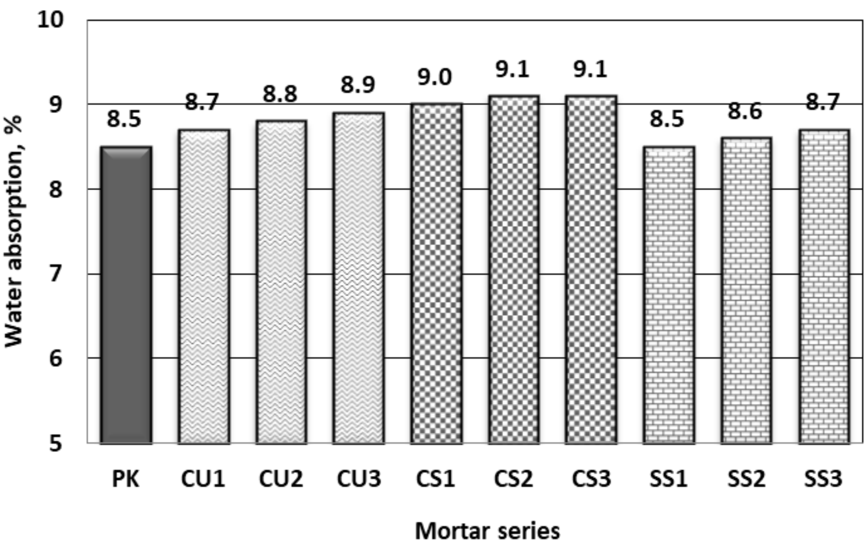

Fig. 4. Water absorption of cement mortars

4. Conclusions

The research results showed that waste materials can be used as a substitute for sand in cement mortars. The use of usable and sanitary ceramics in the amount of 10, 20 and 30% causes an increase in the average compressive strength with the increase of the additive amount. However, in the case of CRT cullet, an increase in compressive strength was observed only for a series of mortars containing 10% of waste material. The use of utilitarian ceramics and sanitary ceramics reduces the decrease of compressive strength of cement mortars after 25 freezing cycles. The lowest drop of compressive strength (3.5%) was found in cement mortar samples containing 30% sanitary ceramics. The addition of CRT glass cullet did not have much impact on this mortar property. The use of waste materials had little effect on water absorption of mortars. The difference between the results obtained by the standard mortar and mortar with waste materials was a maximum of 0.6%.

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