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Using waste in cement composites as a way to sustainable production of building materials

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In accordance with the principles of circular economy, using waste in building materials production is becoming more and more important. Incorporation of industrial waste in concretes has been studied for several years. Widely produced silica fume, fly ash and blast furnace slag have been mainly investigated. However, in these cases, attention was primarily given to examination of the mechanical parameters of cement composites and not to the circular economy aspect. This paper is focused on less investigated industrial waste with replacement of cement with eggshells, by-pass from cement industry and recycled glass. Besides the mechanical parameters (compressive strength, water absorption etc.), the authors also studied the chemical characteristics and durability parameters of these cement composites being subjected to aggressive environment of modelled acid rain. Thermal analysis (DSC/TG) was used to evaluate the hydration phases and the hydration rate of various composites, X-ray methods (XRF and XRD) and infrared spectroscopy (FTIR) were used to characterize the prepared waste-base samples. The experimental results showed differences in hydration of composites and durability parameters of the cement composites with different cement substitutes. The rapid chloride penetration test was found to be an effective tool to compare and predict the resistance of the composites against the aggressive environment.

Materials and methods

Mixture no. 1. (CEM): **cement** composite without cement substitute.

Mixture no. 2. (BFS): cement composite with 20 wt. % cement replacement by **blast furnace slag**.

Mixture no. 3. (BD): cement composite with 20 wt. % cement replacement by **bypass dust**.

Mixture no. 4. (ES): cement composite with 20 wt. % cement replacement by **eggshells**.

Mixture no. 5. (GL): cement composite with 20 wt. % cement replacement by **recycled glass**.

Figure 1: Cement mortars for the experiment.

Sample preparation and devices for mechanical tests

Figure 2: Laboratory stirring gear, metal molds with dimensions 40x40x160 mm, vibrating table, prepared cement samples and round cement samples for RCP test, planetary mill, samples hydronation, compression machine.

Analytical devices for estimating the parameters of durability

Figure 3: X-ray fluorescence spectrometry, X-ray diffraction analysis, Thermogravimetry-differential scanning calorimetry, Corrosion Chamber for acid rain simulation (1 year in real conditions), Rapid Chloride Permeability Test Apparatus for ion diffusion.

Results and discussion

Table 1. Characterization of mortars before the corrosion experiment.

Sample	Bulk Density after 28 days [kg/m^3]	Compressive Strength after 28 days [MPa]	Absorbency [%]	Ion Diffusion [C]
CEM	2090	56.70	7.43	142.06
BFS	2060	56.37	7.59	92.34
BD	2010	20.7	9.61	170.29
ES	2020	37.77	8.17	164.99
GL	2060	37.88	7.71	139.85

Table 2. Evaluation of changes in chemical composition due to the aggressive acid rain.

Sample	Exposition	Ca/Si
CEM	Before	0,79
	After	0,66
BFS	Before	0,62
	After	0,85
BD	Before	0,76
	After	0,68
ES	Before	0,75
	After	0,99
GL	Before	0,74
	After	0,68

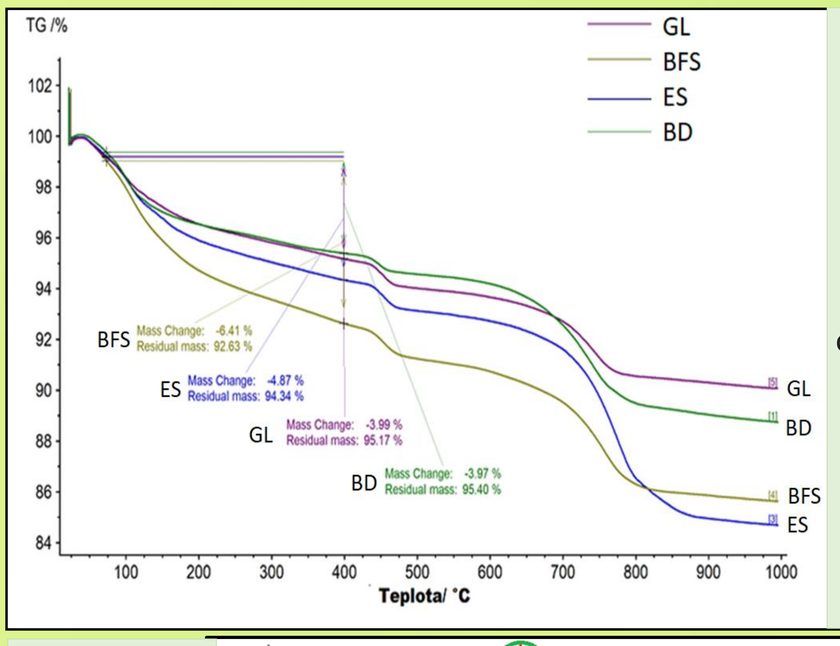
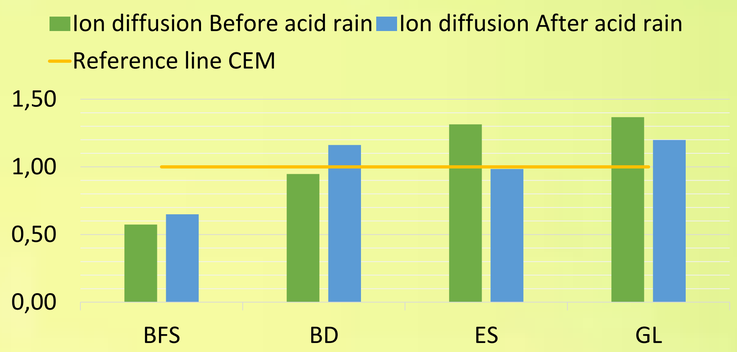


Figure 4: TG curve of cement composites of investigated admixtures.

Figure 5. Ion diffusion according to RCPT before and after acid rain.



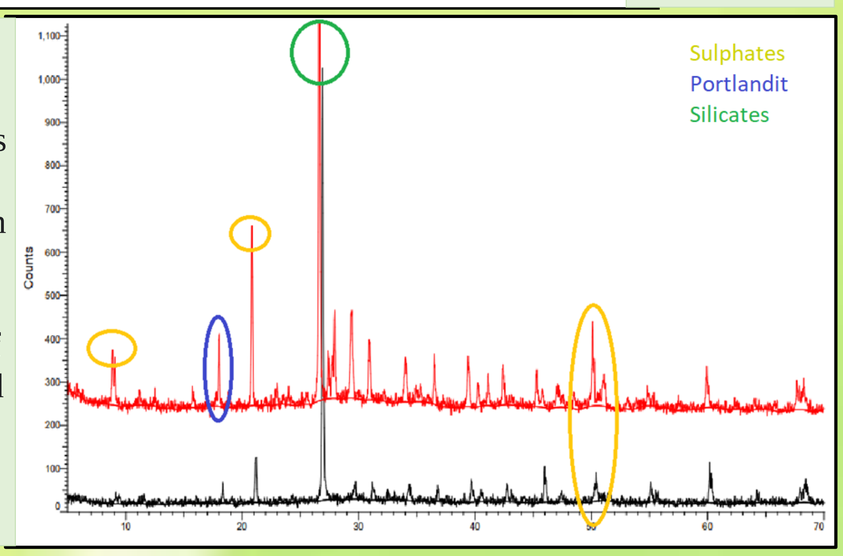


Figure 6: XRD analysis before and after acid rain for BD sample. Formation of sulphates and portlandites.

Conclusion

Presented paper is focused on durability parameters of waste-based cement composite materials after acid rain influence which simulation was equal to 1 year in real conditions.

According to observation, the proper wastes were chosen to be suitable as cement substitution. After chemical analysis before and after acid rain exposition, the results are in favour to **BFS and ES samples** mainly according to the durability analysis such as XRF, XRD, DSC/TG analysis and RCPT.

Aknowledgment

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