USE OF RECYCLING BINDER AS AN EXAMPLE OF REDUCTION CEMENT IN CEMENT COMPOSITES

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Higher number of people and economic growth imposes an additional load on already limited natural resources and will require maintaining of actions aimed for neutralization of influence on the climate changes. As a key component of concrete the cement plays crucial role in the resource management, therefore the problem of reuse of old grout is an object of research of many scientists due to concrete recycling and recycled materials in the context of their efficient management and environment protection (Bołtryk and Kalinowska-Wichrowska 2016; Kalinowska-Wichrowska 2016; Duan and Poon, 2014).

The goal of research undertaken in this article is to demonstrate the possibility of reuse of binder obtained from concrete recycling as the cement substitute in the cement composites. Reduction of amount of used cement coming from the factory (where most of CO_2 is emitted to the atmosphere during clinker baking) limits emission of that gas. In Table is showed total emission of main air pollutants.

Table 1. Total emission of main air pollutants (GUS 2016)

Specification	2010	2014
	In thousands of tons	
Carbon dioxide	334026	310307
Sulphur dioxide	970	800
Nitrogen oxides	874	723
Carbon oxide	3119	2704
Non-methane organic volatile compounds	949	888
Nature	284	282
Ammonia	274	265
Dusts	462	383

Approximately 60% of total CO2 emissions from clinker production are released directly as a result of limestone processing. Most of the remaining 40% comes from burning fuel in the furnace in order to achieve the high temperatures necessary for the formation of clinker minerals. Indirect emission from electricity consumption accounts for about 6% of total CO_2 emissions.

1. Object and methodology of own research

1.1. Characteristics of raw materials

- Cement CEM I 42,5R and corresponding to the requirements of standard PN-EN 197-1 Cement – Part 1: Composition, specifications and conformity criteria for common cements. Only the fine aggregate in form of standardized sand has been used for the tests.
- Recycling binder

Due to possible presence of contaminants of "industrial" origin in the recycling binder, which might interfere with obtained tests results, the experiment has been realized with use of secondary binder obtained as a result of processing of previously prepared laboratory samples of cement grouts. The grouts have been prepared from cement and water in w/c ratio: 0.35; 0.45; 0.55 in moulds 4x4x16 cm. After 28 days of curing in the water conditions the samples of grouts have waited for another month in air-dry conditions. Then they have been crushed in the jaw crusher to dimensions of approx. 20 mm. In such form, they have been placed in the thermal furnace to be subjected to baking in temperatures defined in the experiment plan. After that process, the material has been remilled for approx. 20 minutes in micro Deval drum to obtained as high specific surface as possible. During remilling the whole charge consisted of fraction < 0.125 cm and the specific surface oscillated in range of 3500-3800 cm^2/g. Figure 1 shows process of preparing recycled binder.

The recipe of cement composites has been assumed as for standard mortars according to PN-EN 196-7: 2009 Methods of testing cement - Part 7: Methods of taking and preparing samples of cement, where w/c ratio = 0.5.

Figure 1.The milling process of preparing recycled binder.

For forming of beams 40x40x160 mm the Portland cement CEM I 42.5R has been used, which 25% (w/w) has been replaced with recycling material. After 28 days of curing in water conditions the samples have been subjected to bending and compression tests. The test results are presented in section 4.

- sand

For making samples, this is a CEN standard sand filter for laboratory testing supplied from KWARCMIX. It is certified to PN-EN 196-1. Sand 2 mm fraction is supplied in bags with a net weight of 1350 ± 5g and the grains distribution in Table 2.

Table 2.Sand grading

Dimension of square mesh side **[mm]**	2,00	1,60	1,00	0,50	0,16	0,08
Total residue on the sieve **[%]**	0	7±5	33±5	67±5	87±5	99±1

1.2. Test methodology

The compression strength testing has been realized for 6 randomly selected beams 4x4x16 cm from each batch according to standard PN-EN 196-1:2006 Methods of testing cement - Part 1: Determination of strength.

The pozzolana activity has been determined according to standard PN-EN 450-1:2009. Flyash for concrete. Part 1: Definition, specifications and conformitycriteria.

The percent content of individual sizes of particles in the recycling material after the thermal and mechanical processing has been determined with use of particle size analyser Fritsch Analysette 22 NanoTec plus.

The measurement of surface area according to Blaine in automatic Blaine's Apparatus.

2. Research experiment

2.1. Experiment plan

To determine the influence of thermal processing of recycling binder on selected properties of cement composites the research experiment has been planned, consisting of 9 basic batches and 1 control batch (no. 10) not consisting the recycling binder.

In the experiment two factors (X_1, X_2) have been taken into consideration, each of three variation levels: X_1 – baking temperature of recycling binder (550, 650, 750 °C);

X_2 – time of baking recycling binder (30; 60; 90 min).

The w/c ratio of old cement paste which was crushed was constant0,45.

The experiment plan including coded values of variables is presented in table 3.

Table 3. Plan of research experiment

Batch no.	X_1- baking temp. [°C]		X_2- time of baking (min)	
1	-1	550	-1	0.35
2	-1	550	0	0.45
3	-1	550	1	0.55
4	0	650	-1	0.35
5	0	650	0	0.45
6	0	650	1	0.55
7	+1	750	-1	0.35
8	+1	750	0	0.45
9	+1	750	1	0.55
10	Control batch 100% cement			

2.2. Realization and curing of samples

Batches have been realized with use of automatic laboratory mixer. First the loose components have been weighed and mixed for 5 minutes, then water has been added and mixing lasted another 10 minutes. Such prepared amount of material has been placed in the steel mould allowing for simultaneous forming of three samples of dimensions 4x4x16 cm. Then the samples in the mould have been consolidated on the vibration table. After removing from the mould the samples have been placed in the water basin of temperature of 20°C until realization of proper tests.

3. Results of tests and discussion

The highest results of compression strength have been obtained for the composites including the recycling additive subjected to thermal processing in 650°C (batches 4, 5, 6). The values of obtained strength in those batches equal the results for the control batch (10) without the recycling additive, and in case of batch 6 strength has increased by 7%. According to test method described in PN-EN 450-1:2009 the tested material reveals the pozzolana properties when the compression strength of composite containing 25% of material substituting the cement is 75% of control sample. In tested composites all strength results for batches where the recycling material has been subjected to baking in 650°C and 750°C had revealed the pozzolana properties. Only in batches where the thermal processing of recycling material was 550°C (batches 1, 2, 3) the pozzolana properties have not been activated. It is assumed that in such range of temperatures there is still significant amount of not decomposed portlandite present (Krzywobłocka- Laurów, 1998). The results areshown in figure 3.

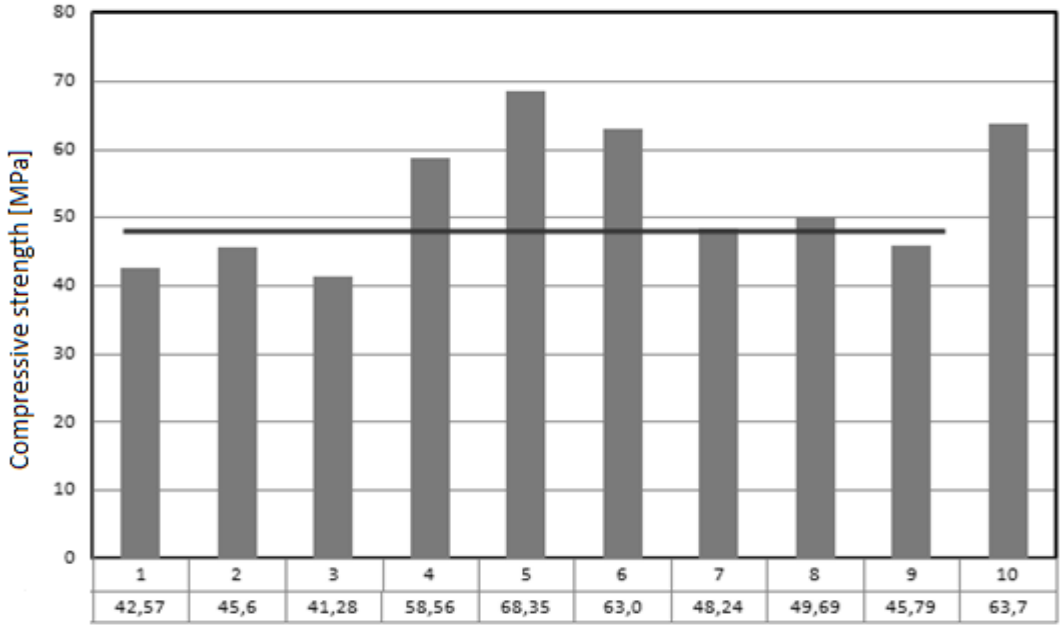

Figure 3.The results of compression strength for cement composites with addition of recycling binder (the horizontal line crosses batches where material has revealed the pozzolana properties)

Beside the temperature factor the realized test examined also the influence of w/c ratio of recycling binder on obtained compression strength of cement composites. As figure 4 shows, changes of time baking in various accompanying baking temperatures had no influence on the compression strength values. Therefore, that factor may be considered insignificant, but it would be confirmed by the statistical analysis omitted in the article.

Lack of influence of variable time of baking recycling material on compression strength results mostly from high processing temperatures and milling degree. As described above, the recycling material after the baking process has been subjected to remilling in the planetary mill down to the specific surface similar to that of cement 42.5 R, and those processes might have had the main impact on such effect.

In the figure 4 is showed the all results of surface area of recycled binders.

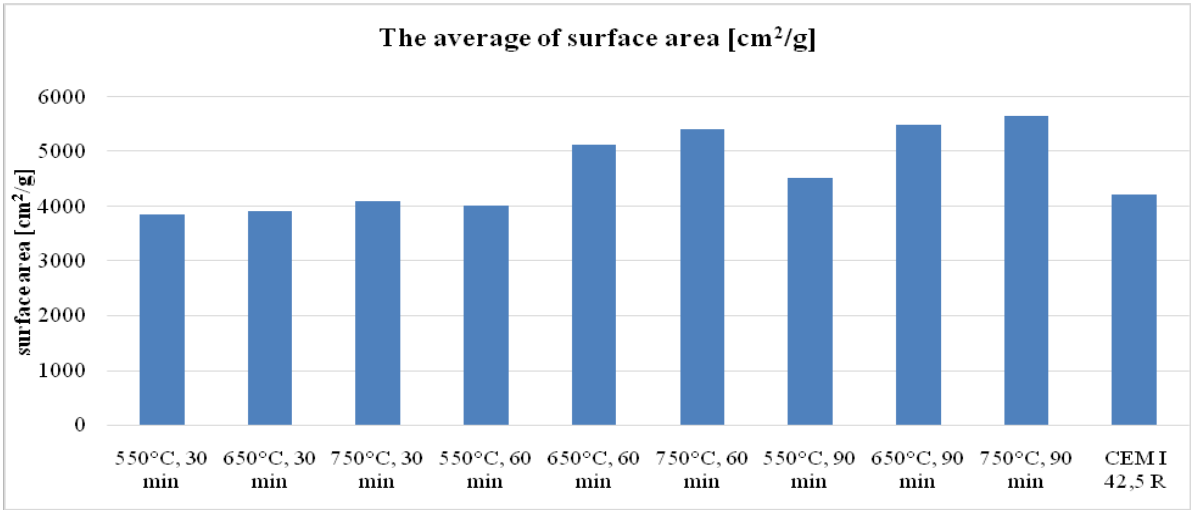

Figure 4. The results of average surface area of recycled binders

The high specific surface area of the material influences the improvement of its binding properties (Jamroży 2015). In the case of recycled binders, the reference material was CEM I42,5R for which the manufacturer declared a surface area of 4210 g/cm^2. It has been observed that the recycled binder obtained from the calcination of the fine fraction (crushed cement slurry) at 650°C and 750°C has no significance for its duration, resulting in high surface area values exceeding 5000 cm^2/g. During the preparation of recycled binders, it was observed that the thermal treatment at 750°C caused the material to break into larger particles and adhere to the wall of the mill. This was not the case for the preparation of the remaining recycled binders. This is important technical information.

4. Summary

The presented results of tests have confirmed that after suitable processing the tested recycling material reveals the pozzolana properties in composites, influencing the behaviour or even in some case the improvement of compression strength values. The optimum strengthparameters and the highest level of pozzolana activity index have been obtained for the baking temperature of 650 degrees. Increasing the processing temperature by 650°C caused drop of strength and pozzolana parameters.

The suitability of tested material as an active additive is also significantly influenced by the milling degree, close to specific surface of cement from which the old grout comes. In realized tests the assumed w/c ratio of recycling material had no influence on the composite strength properties. As the tests results show, the recycling material produced in such way may be successfully used as an alternative for cement.

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