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Investigation of Mechanical Properties of Cement Pastes with Fine Recycled Concrete as Partial Replacement for Portland Cement: Kind of Method High-Speed Milling

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Abstract. This article deals with mechanical activation of old concrete by high-speed mills and using recycled concrete powder as a partial replacement for cement. In particular, we focus on mechanical properties of cement pastes containing different kinds of fineness of micronized recycled concrete powder. As recycled materials, we used the monolithic construction of a column from a construction of supporting structures. Recycled material was milled by company LAVARIS Ltd. at high-speed milling process with different types of milling. Mechanical properties were obtained by non-destructive (resonance method) and destructive method. Investigated mechanical properties were the dynamic modulus of elasticity and the dynamic shear modulus, flexural strength and compressive strength. Results obtained from these materials were compared with the reference material.

Introduction

Only the fraction larger than 1 mm is used in this recycling. However, the problem arises when processing a very fine fraction (<1 mm) of recycled concrete. One option is thermal activation of an old cement paste [1, 2]. Due to high demands on energy consumption and CO_2 production, it is particularly suitable for sustainable and environmentally friendly methods where the very fine fraction of recycled concrete is used in its raw form [3, 4].

Unlike mentioned researches, we focused directly on mechanical activation of old cement pastes. The article deals directly with the use of possible hydration potential of micronized concrete. The micronizing of the old cement paste into fine particle results in uncovered unhydrated clinker minerals, which can further hydrate upon contact with water [5]. In addition, the size of the grains of inert portions such as filler and the old cement matrix will be reduced. Small inert grains in the future composite can create nucleation centers for Portland growth and thus positively affect the hydration of cement. In addition, small grains may have a micro-filler function [6].

Recycling through high-speed milling is a highly energy-intensive method. For this reason, its optimization is very important. Company LAVARIS ltd. has patented grinding elements and a new generation of high-speed mills that can grind recycled material in two levels and have several possible sampling points [7]. Depending on the size of the particle size, individual sampling points can be used. Using these mills, you can optimize the entire course of recycling of materials so that it is economical and environmentally friendly. A similar way of optimization has already been used to recycle waste marble sludge [8].

Materials and Specimens

Cement pastes composed of 70 wt. % Portland cement CEM I 42.5R from Radotin and 30 wt. % non- / micronized recycled concrete has been prepared for investigating the impact of micronizing. Recycled concrete was obtained from an old construction of a column. The difference between individual specimens was in the mode of high-speed milling and sampling of the micronized recycled concrete. Testing was performed on beams of dimensions equal to 40 × 40 × 160 mm.

Micronized recycled concrete without milling (REC) had average grain size of 304 microns. Micronized recycled concrete I-level milling removed from the front of the mill (REC I-A) had average grain size of 48 microns. Micronized recycled concrete I-level milling removed from the middle of the mill (REC I-B) had average grain size of 6.17 microns. Micronized recycled concrete I-level milling removed from behind of the mill (REC I-C) had average grain size of 5.51 microns. Micronized recycled concrete II-level milling removed from the front of the mill (REC I-A/II-A) had average grain size of 38.7 microns. Micronized recycled concrete II-level milling removed from behind of the mill (REC I-A/II-B) had average grain size of 3.04 microns.

Experimental methods

Investigated mechanical parameters were the dynamic modulus of elasticity, the dynamic shear modulus, flexural strength and compressive strength. Values of the dynamic shear modulus, the dynamic modulus of elasticity, flexural strength and compressive strength of the specimens were determined after 28 days.

Resonance method was used for non-destructive testing; its principle was explained in the work of Topič et al. [9]. Measurement of the dynamic modulus of elasticity was carried out using the measurement line from Brüel & Kjær, consisting of a measuring unit type 3560-B-X12 impact hammer type 8206 and an acceleration sensor type 4519-003 53422 assemblies were connected to the control computer. The dynamic modulus of elasticity was achieved by using the basic longitudinal natural frequency of specimens and the dynamic shear modulus was achieved by using the basic torsional natural frequency of the specimen. The mass of all specimens was measured and the dimensions were recorded before the resonance method was applied. Bulk density was calculated from these values.

The flexural and compressive strength were determined using the Heckert device, model FP100. The testing was displacement controlled at a constant rate of 0.1 mm/s in the case of three-point bending and 0.3 mm/s for the compressive test. The distance between supports for three-point bending test was equal to 100 mm. The uniaxial compressive test was performed on the broken halves of the specimens with effective dimensions of 40 × 40 × 80 mm.

Results and Discussion

Results (Fig. 2) show the effect of fineness of micronizing recycled concrete on mechanical properties of cement pastes, namely dynamic modulus of elasticity and dynamic shear modulus. Results do not show a very positive effect of milling on dynamic modulus of elasticity (Fig. 2). The greatest effect can be seen in the non-milled recycled material where the dynamic modulus of elasticity is higher than in the reference specimen. The average value of dynamic modulus of elasticity of references specimens was 27.1 ± 0.1 GPa. Specimens with non-milled recycled materials had the value of dynamic modulus of elasticity equal to 28.7 ± 0.3 GPa and the specimens with finest milled recycled concrete 22.6 ± 0.3 GPa. The same effect can be seen in the case of the dynamic shear modulus and compressive strength (Fig. 2 and Fig. 3). The average values of dynamic shear modulus were equal to 10.8 ± 0.04

GPa in the case of reference specimens, 11.5 ± 0.12 GPa in the case of specimens with non-milled recycled concrete and 9.1 ± 0.24 GPa in the case of specimens with finest milled recycled concrete. The average values of compressive strength were equal to 110.7 ± 3.2 MPa in the case of reference specimens 101.0 ± 4.6 MPa in the case of specimens with non-milled recycled concrete and 79.9 ± 5.6 MPa in the case of specimens with finest milled recycled concrete.

This effect was caused by decrease values of the bulk density. Average values of the bulk density were 2113 ± 8 kg/m^3 in the case of reference specimens, 2122 ± 12 kg/m^3 in the case of specimens with non-milled recycled concrete and 1986 ± 24 kg/m^3 in case specimens with finest milled recycled concrete. The reduction in bulk density indicates an increase in porosity that has a negative effect on these mechanical properties. One of the possible ways to eliminate this effect is to use plasticizers.

Flexural strength is shown in figure 2. The higher value of flexural strength had the specimen with milled recycled concrete (REC I-A), namely 4.1 ± 0.12 MPa. The references specimen had the average value of flexural strength equal to 2.5 ± 0.48 MPa. The results showed that average grain size around 40 microns had the positive effect on flexural strength. This effect is due to the fact that recycled concrete forms a supporting structure in the cement composite. The best way of micronizing is a one-level milling with sampling at the front of the milling process.

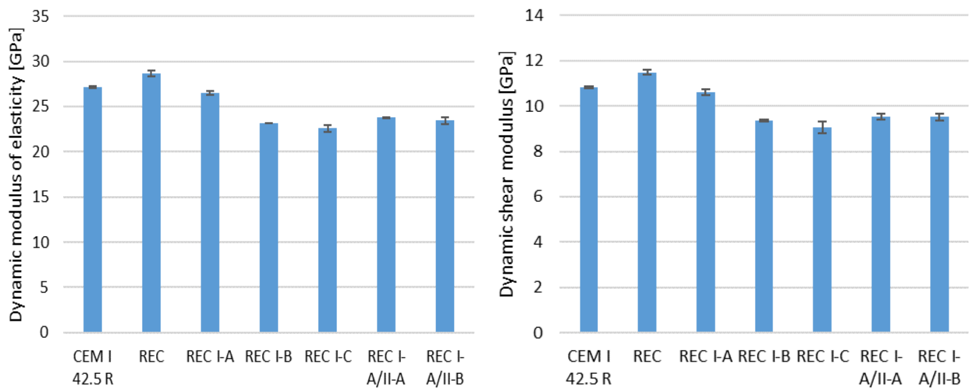

Fig.1 Comparison of dynamic modulus of elasticity and dynamic shear modulus (with standard deviations)

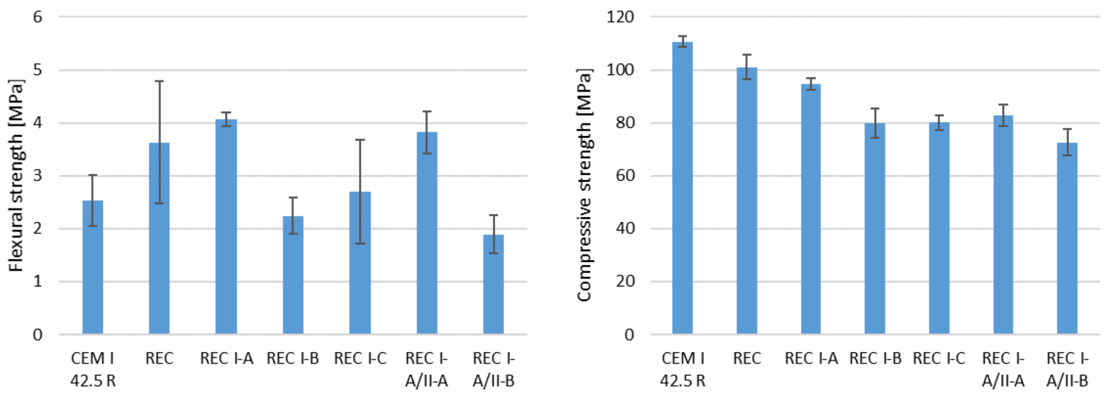

Fig.2 Comparison of flexural strength and compressive strength (with standard deviations)

Conclusions

Results does not show a very positive effect of milling on mechanical properties. It can be seen that the non-milled recycled concrete had the higher value of dynamic modulus of elasticity than references specimens. The greatest effect of milling process can be seen in the recycled concrete I-level milling removed from the front of the mill, where flexural strength is higher than in the reference specimen and the value of compressive strength was lower about 15 MPa. This is due to the fact that the recycled material had negative effect on porosity of cement composites. One of the possible ways to eliminate this effect is to use plasticizers. Future work will be dealing with using plasticizer with micromilled recycled concrete in cement composites.

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