Cement Paste with Recycled Concrete Powder: Long Term Development of the Strength

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Abstract: Presented paper deals with using of a recycled concrete powder (RCP) modified by a high speed as microfiller and partial binder replacement in cement pastes. This approach allows to exposed unhydrated cement grains to further hydration. Such use of recycled concrete powder could lead to cost reduction of a concrete mixture. The flexural and compressive strength on samples made of Portland cement containing 0, 33, and 67 wt. % of a recycled concrete powder were determined. Those mechanical properties were determined in several times during 14 months. Results show that 33 wt. % cement replacement seems like limited value, when mechanical properties in long term scale are comparable with a reference sample. Samples with 67 wt. % of RCP had significantly lower strength compared with reference samples.

Keywords: Cement; recycled concrete; cement replacement; mechanical properties, strength.

1 Introduction

Waste production and its accumulation is a worldwide environmental issue. Development of new methods and procedures for effective reuse of waste materials helps to reduce the amount of landfill sites and to protect environment and non-renewable resources [1]. Concrete is the most widely used building material. For this reason, it is necessary to solve the problem of concrete recycling. During recycling of old concrete occurs a problem with processing very fine fraction having a grain size <1 mm (powder) [2]. So far has not been found suitable application for this fine concrete waste.

Using recycled concrete powder (RCP) as a raw material for Portland clinker production [3] or as alternative heat treated binder [4] belong among several possibilities of a recycled concrete powder. Taking into account the heat consumption and the production of CO_2, which contributes to environmental degradation, the previous methods are no more environmental friendly and sustainable. On the other hand non-renewable natural resources are preserved. The possibility of using recycled concrete powder as filler for asphalt mixtures appears as environmental friendly and cheaper. The possibility to use the powder for production of geopolymeric binder [5] is also very interesting. Recent studies suggest that it is also possible to use recycled concrete powder as a partial replacement of cement [6, 7].

This paper is focused on using the recycled concrete powder RCP as a microfiller and cement replacement. In this case the old railway sleepers are recycled. In addition the fine fraction of recycled concrete is treated by high speed milling. This approach allows exposed unhydrated cement grains to further hydration [8,9]. Such use of the recycled concrete powder could lead to cost reduction of a concrete mixture.

2 Materials and Samples

The samples were made of Portland cement CEM I 42.5 R produced in Radotín (CZ) and a fine recycled concrete powder (RCP) prepared from old railway sleepers. Sleepers were crushed to particle-size fraction 0/63 mm. The final fine-grained product was obtained by grinding of separated material with a particle size 0/16 mm by using a high speed mill made by LAVARIS Ltd. Particle size distribution of RCP used for production of the tested samples was analyzed by laser device Fritsch Anlysette 22 MicroTec plus and it is presented in Tab. 1. The specific surface area of RCP measured by the Blaine method was 412 m²/kg. Particle size distribution of RCP is similar to a particle size distribution of Portland cement CEM I 42.5 R.

Tab. 1: Particle size distribution of RCP.

Grain size [μm]	0	0.5	1	2	4	8	16	32	64	128	160
Cumulative amount [wt. %]	0	1.2	3.5	8.8	19.2	36.5	59.5	82.0	96.2	99.9	100

Three sets of samples with different amount of RCP were prepared and tested (Tab. 2). Each set contained 24 prismatic samples having dimensions of 40 × 40 × 160 mm. To reach similar workability of the mixtures, the water/mixture ratio varied for each set. Consistency of the mixtures was determined by flow expansion test. The samples were cured for the next 28 days in water at the temperature of 21 ± 2 °C. After 28 days the samples were stored in laboratory conditions at the temperature of 21 ± 2 °C and the relative humidity of 50 ± 5 %.

Tab. 2: Composition of the mixtures.

Mixture	Cement (CEM I 42.5 R) [g]	RCP [g]	Water/mixture mass ratio	Flow expansion test [mm]
A (REF., 0 wt. % RCP)	1000	-	0.35	130
B (33 wt. % RCP)	670	330	0.38	130
C (67 wt. % RCP)	330	670	0.42	130

3 Measurement methods

The flexural and compressive strength were determined on the 28, 100, 287 and 409 days old samples using the Heckert device, model FP100. Each test set contained 6 samples. 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 during the compression test. The distance between supports during the 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.

4 Results and Discussion

The flexural strength results are presented in Fig. 1. It is obvious that higher amount of RCP in mixture after 28 days has a negative influence on the flexural strength. However, after 100 days the flexural strength of the samples B with 33 wt. % of RCP was almost 2 times higher compared with the reference sample. The samples C with 67 wt. % of RCP have the comparable flexural strength as the reference samples. After 287 days the flexural strength of the reference sample was almost same as in the previous time. In case of samples B the flexural strength was lower than in previous case and in case of samples C the decrease was almost 50 %. After 409 days the flexural strength of samples A and B decreases about 90 and 60 %. Flexural strength of samples C increase about 60 % and it was little higher than after 100 days. Based on results it can be assumed that samples B are comparable or have a little higher flexural strength in time than reference samples. Broad ranges of the flexural strength between the same samples in different times could be caused by little differences in mixing and molding because each set of the samples was mixed separately.

The compression testing results are presented in Fig. 2. The negative influence of the cement replacement on compressive strength after 28 days is significant only in case of sample C, the compressive strength was lower about 65 %. Samples with 33 wt. % of RCP have comparable compressive strength as the reference samples. Difference in the compressive strength between the samples A and B is obvious after 100 days. The strength of samples A reaches to 120 MPa and of samples B only to 78 MPa. The compressive strength of samples C is significantly lower. During time after 100 days to 409 days the compressive strength of samples

A and B declined about 45 and 25 %. The compressive strength of samples C stabilized around 30 MPa during whole time after 100 days. According to the results of compressive strength, it is obvious that cement paste with recycled concrete powder has lower strength at 100 days. But in construction practice, the values of strength at 28 days are supreme and in this case the compressive strength is comparable with the reference samples and the samples B. Moreover the decrease of compressive strength in case of the reference samples is more significant than in case of the samples B. Because of this fact the value of the compressive strength after 409 days differs only about 10 %. The compressive strength of the samples C caused by a high content of RCP, is too low for practical and economical use in construction.

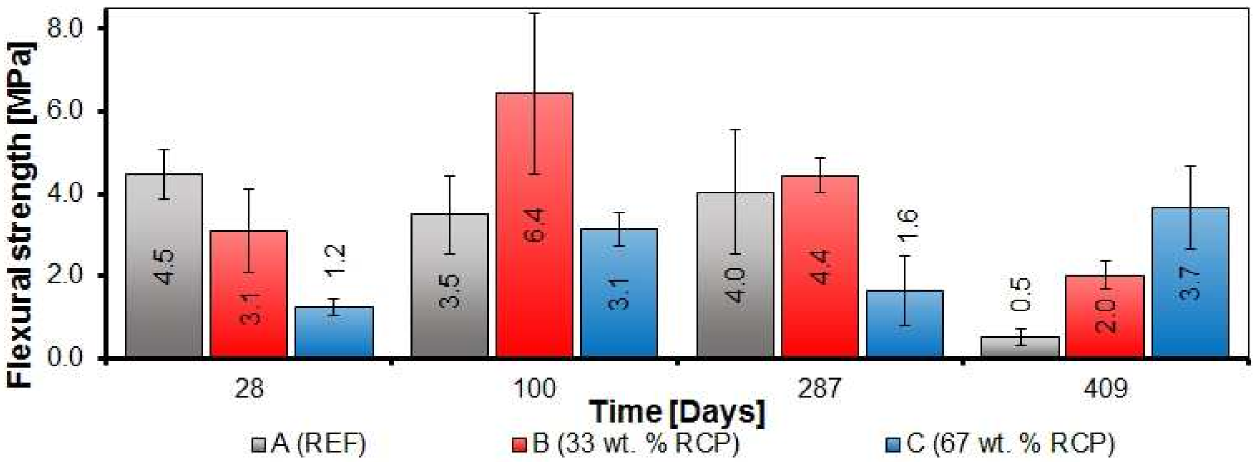

Fig. 1: Flexural strength development of the cement pastes with different amount of a recycled concrete powder.

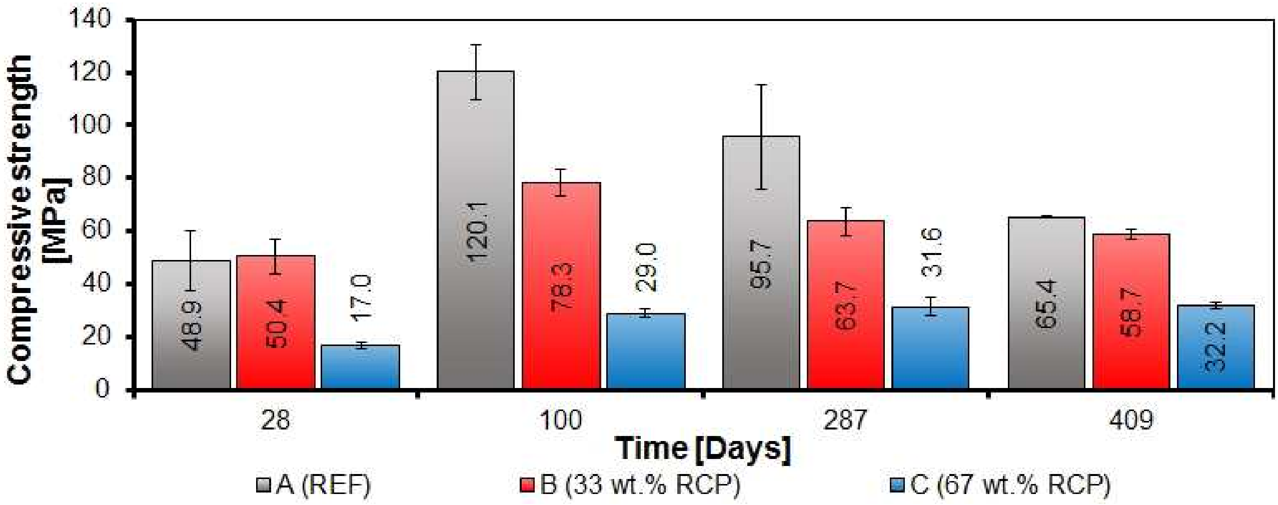

Fig. 2: Compressive strength development of cement pastes with different amount of a recycled concrete powder.

5 Conclusions

This work is focused on the development of the flexural and compressive strength of the cement paste with different amount of a recycled concrete powder (RCP) modified by high speed milling. Based on the results it can be concluded that:

- high speed milling process enables reuse of the unhydrated cement grains and some hydraulic properties and microfiller properties was achieved,
- the flexural strength of the samples with 33 wt. % of RCP was higher after 100, 287 and 409 days compared with the reference samples,

- broad ranges of the flexural strength between the same samples at different times could be caused by small differences in mixing and molding because each set of the samples was mixed separately,
- the samples with 33 wt. % of RCP have the comparable compressive strength with the reference sample,
- during time after 100 days to 409 days the compressive strength of samples A and B declines about 45 and 25 %,
- the results suggest that RCP could be used as a partial cement replacement (if added below 33 wt. %) with minimal decrease in strength, while the cost reduction is still rather significant.
- compressive strength of samples C caused by a high content of RCP, is too low for practical and economical use in construction.

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