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SHRINKAGE OF THE CEMENT PASTES WITH DIFFERENT AMOUNT OF FINELY GROUND RECYCLED CONCRETE

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ABSTRACT

Complete recycling of the old concrete is very problematic mainly because of fine fraction (< 1 mm). Some studies focus on using recycled concrete powder as thermal activated binder or alternative raw material for manufacture of the Portland clinker. But those approaches are not sustainable and environmental-friendly. Use recycled concrete powder as cement replacement or filler seems to be a better way. This study deals with influence of finely ground recycled concrete (FGRC) on shrinkage of cement pastes. Finely ground recycled concrete was produced by LAVARIS Ltd. by using high speed mill. The old concrete was obtained from old railway sleepers. Four sets of cement paste with different amount (0, 33, 67, 100 wt. %) of FGRC were prepared. Increasing amount of FGRC negatively influenced shrinkage of the cement paste. It is mainly caused by increasing w/c ratio due to higher water demands of FGRC. Improvement could be achieved by using high amount of superplastizers.

***Keywords:* Cement Paste, Concrete Powder, Finely Ground, Recycled Concrete, Shrinkage, Substitute Binder**

I. INTRODUCTION

Recycling of the concrete waste is relatively well known in construction practice. Old concrete is usually crushed and separated into several fractions. Low quality concrete waste can be used for embankment or unbound roads [1]. Coarse fraction of concrete waste can be used as recycled aggregate into new concrete mixture [2]. Lack of recycled aggregates is the increased water absorption which negatively affects the workability, the mechanical properties and durability of the concrete. But those effects could be diminished by using proper admixtures and additives. The concrete with recycled aggregate can be comparable with concrete with natural aggregate [3]. A problem arises with processing very fine fraction having a grain size <1 mm (powder) generated by the recycling of old concrete. So far has not been found suitable application for this fine concrete waste.

There can be found several ways in current research works. Recycled concrete powder mainly consists of hardened cement paste and aggregate residues. Therefore first attempts try thermally reactivate binding properties of the concrete powder. It was found that the cement paste in a concrete powder can be dehydrated by proper heat treatment. Studies show that the hardened cement paste in concrete powder treated at 500 - 800 ° C is composed mainly of dehydrated C-S-H gel, CaO and partly from C-H. After mixing with water, there was a restoration of the hydration products of C-S-H gel, ettringite and $CaOH_2$ [4].

Similar way for using recycle concrete powder is partial replacement of raw mixture for Portland clinker production. Studies have shown that it is possible to utilize a recycled concrete powder as an alternative to conventional raw materials, primarily for the source of SiO_2 and in some cases, due to high content of CaO, for limestone also [5]. But the total amount of recycled material in mix should not exceed 30 % [6].

However both mentioned methods require high amount of energy and produce CO_2. On the other hand non-renewable natural resources are preserved. As environmental friendly and cheaper appears the possibility of using recycled concrete powder as filler for asphalt mixtures [7]. Very interesting is also the possibility to use the powder for production of geopolymeric binder [8]. Recent studies suggest that it is also possible to use recycled concrete powder as a partial replacement of cement [9, 10]. Therefore this study is focused on the influence of cement replaced by recycled concrete powder on shrinkage of the cement paste with finely ground recycled concrete (FGRC).

II. MATERIALS AND SAMPLES

The samples were made of Portland cement CEM I 42.5 produced in Radotín and finely ground recycled concrete. FRGC was produced by LAVARIS Ltd. by using high speed mill. The old concrete were obtained from old railway sleepers type PB2 and SB8. FGRC has fraction 0 – 65 µm and the specific surface area was equal to 412 m²/kg. Four mixtures were prepared where cement was replaced by 0, 33, 66 and 100 wt. % of FGRC (Table 1).

Table 1: Composition of the Tested Samples

Mixture	Cement (CEM I 42.5 R) [g]	FGRC [g]	Water/mixture mass ratio	Flow expansion test [mm]
A (REF., 0 wt. % FGRC)	1000	-	0.35	130
B (33 wt. % FGRC)	670	330	0.38	130
C (67 wt. % FGRC)	330	670	0.42	130
D (100 wt. % FGRC)	-	1000	0.45	130

Due to different behavior of cement and FGRC when mixed with water, the water-mixture ratio was within the range between 0.35 (mixture A) and 0.417 (mixture D), depending on the amount of FGRC. Unifying parameter for these mixtures was workability defined by the flow expansion test. This solution provided a similar homogeneity for all mixtures and in the case of mixtures containing FGRC reduced the size and amount of technological pores in the hardened composite [11]. Each set contained 6 prismatic samples having dimensions of 40 × 40 × 160 mm. The samples were removed from casts after 2 days and shrinkage measurements were performed. The specimens for microstructure examination by optical and scanning electron microscopy were cured for 28 days in water at the temperature of 21 ± 2 °C.

III. MEASUREMENT METHODS

The first step of measurement was the length measuring of each box in mold before the mixture was placed into. The measurement of samples was performed after 2 days when they were removed from casts. The resulting shrinkage of each sample was related to the length of 1 m. The microstructure of the samples was examined using scanning electron microscope in BSE mode. A Philips XL30 ESEM-TMP FEI scanning electron microscope was used for identification the individual phases and their amount at 100× and 250× magnification. SEM was used in the BSE mode at low pressure (9–10 Pa) and at accelerating voltage set to 30 kV.

IV. RESULTS AND DISCUSSION

Diagram of shrinkage is presented in Fig. 1. It is obvious that increasing amount of FGRC negatively influences shrinkage of the cement past. This difference between shrinkage of the samples is probably caused by higher water content in mixtures due to higher water demands of FGRC. Higher shrinkage could be also caused by changes in hydration process of the samples with FGRC. This is supported by SEM images (Fig. 2) where the distribution of the various phases within the cement paste can be detected [12]. The aggregate contained in FGRC can be identified as dark grey spots in the sample B. The decrease of unhydrated cement grains (displayed as white spots) is obvious in case of samples containing FGRC compared with reference sample without FGRC. Given the ratio of cement and FGRC in the sample B, the amount of unhydrated cement grains should be about 33% lower than in the sample A. However, the difference reached almost 60 %.

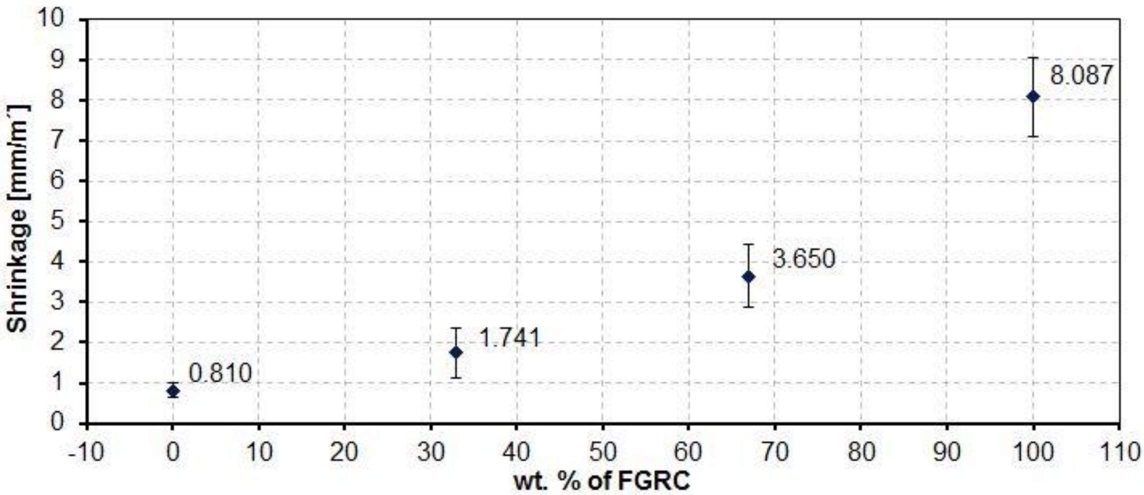
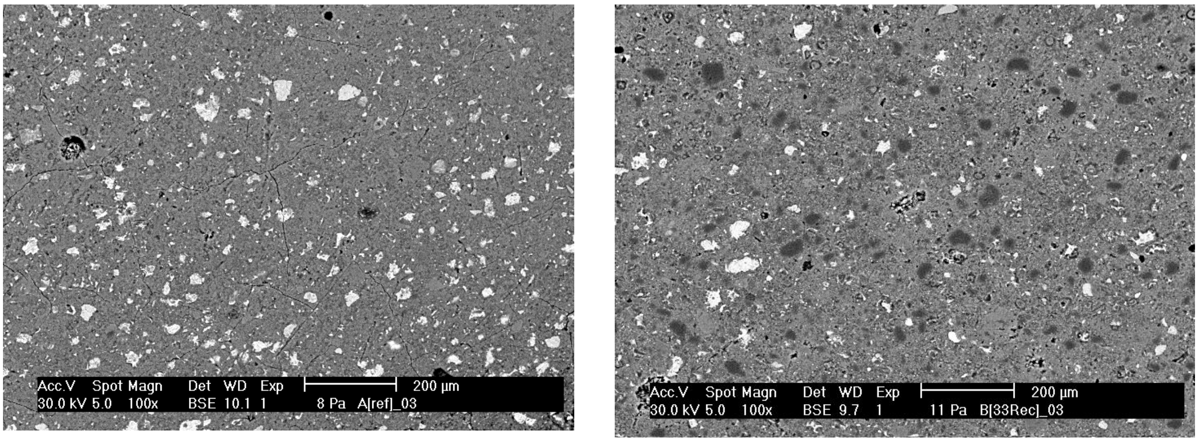


Figure 1: Dependence of shrinkage of the samples on cement replacement by FGRC



a) Sample A (REF., 0 wt. % FGRC) **b) Sample B (33 wt. % FGRC)**

Figure 2: SEM images of the samples with different amount of FGRC at 100 × magnification

V. CONCLUSION

The presented results are a part of the larger research. It was found that FGRC can act as filler and cement replacement. The presented work was focused on the influence of cement replacement by FGRC on shrinkage of the cement pastes. Based on the results it can be concluded that:

- increase in shrinkage directly depends on the amount of FGRC in a sample,
- the samples with 33 wt. % of FGRC have higher shrinkage compared with the reference samples without FGRC, but still not so high,
- higher shrinkage is probably caused by higher water demands of samples with FGRC compared with cement,
- difference in shrinkage could be reduced by using superplasticizers,
- the results in related research suggest that FGRC could be used as a partial cement replacement (if added below 33 wt. %) with minimal negative impact on composite properties.

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