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Effect of Poly(vinyl-alcohol) Amount on Flexural Strength of Cement Mortars with Micronized Recycled Concrete

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Abstract. Main goal of the presented study was to investigate the influence of different curing conditions and different amount of PVA (Poly(vinyl-alcohol)) on flexural strength of cement-PVA composites. Resulting cement-PVA composites was composed of Portland cement CEM I 42.5 R, micronized recycled concrete and PVA with different percentage amounts (0 wt. %, 1.4 wt. %, 2.8 wt. %, 4.0 wt. % and 5.6 wt. %). Two sets of samples were made from each mixture. The first set of samples was stored in water after their removal from molds, while the second set was stored exposed to air at a constant temperature and relative humidity. The flexural strength was measured on samples of size 40 × 40 × 160 mm using a three-point bending test. The results obtained from these materials were compared with reference material.

Introduction

Polymers in cement composites have been used since the 20th century. Since that time many types and forms of the polymers been used for cement modification. Best results in cement composites been achieved by adding latex and polymer resins. Because of the massive consumption of cement composites in the construction industry, growing demands on the mechanical properties and the high cost of latex and resins the other alternative polymers as water soluble polymers are interested [1].

Poly(vinyl-alcohol) (PVA) is a water soluble polymer, which is used for modification of cement composites for construction concretes [2, 3]. Material properties of composites based on cement and PVA achieved better characteristics, e.g. hygric properties, durability, shrinkage or tensile, respectively flexural, strength [4]. On the other hand values of mechanical properties as compressive strength and Young's Modulus are reduced, this phenomena related with higher values of bulk density because supplement of PVA create higher total porosity [5]. Knapen et al. [6, 7] conducted a study in which he tested the influence of water on cement composite with PVAA (polyvinyl alcohol-acetate), some mechanical properties and changes in hydration process was. He observe changes towards to retardation of hydration process and decrease content of $Ca(OH)_2$. Morlat et al. [8] conducted a study in which he used mixture of cement and PVA and examined its compression strength, flexural strength and Young's modulus of elasticity of cement paste. The flexural strength was increased and total fracture energy was increased by a factor of three by adding PVA less than 4 wt. % of cement. The purpose of this paper is to investigate the influence of the recycled concrete powder and conditions of curing after 28 days of hardening on the mechanical properties of PVA-cement composites.

Materials and Samples

Portland cement CEM I 42.5 R Mokrá (65 wt. %), micronized recycled concrete (from concrete gutters with a fraction of 0-0.250 mm (35 wt. %), water and PVA (16 wt. % water solution) were used for preparing of the specimens with different values of PVA. PVA was made by alkaline hydrolysis of polyvinyl acetate in methanol in form of water solution SLOVIOL® R produced by Fortischem, a.s. The recycled concrete was created from the gutters. A high speed mill from LAVARIS Ltd. was used for micronizing of the recycled concrete. Individual material specimen differed in the values of solid PVA (Tab. 1). The six samples with dimensions of 40 × 40 × 160 mm were prepared for each material. One-half of the specimen were placed into a water bath immediately after their removal from molds (W) (24 hours after they were cast) while the other was kept at laboratory conditions (D). Standard laboratory conditions were in a laboratory environment at 22 ± 1 ° C and relative humidity 50 ± 2 %. The composition of individual mixtures can be seen in Table 1. Water ratio was constant, equal to 0.35.

Tab. 1: Composition of the tested specimens.

Samples	Cement [g]	Recycled concrete powder [g]	PVA [g]	Water ratio = 0.35	
				Water from solution PVA [g]	Water [g]
D/W 0.0 %	2275	1225	0	0	1225
D/W 1.4 %	2275	1225	49	257	968
D/W 2.8 %	2275	1225	98	514	711
D/W 4.0 %	2275	1225	140	753	472
D/W 5.6 %	2275	1225	196	1026	199

Methods and Experimental Results

A comparison of basic material properties as workability of fresh mixtures, bulk density, total porosity and shrinkage after 24 hours shows table 2, the tested properties depend on quantity of used PVA. The workability of fresh mixtures defined by the spillage after 20 impulses. The destructive testing was performed using standard procedures. The flexural strength were determined on the 28 days old samples using the Heckert device model FP100. The testing was controlled by a constant rate of 0.1 mm/s, a configuration of a three-point bending was in our case used. The distance between supports for three-point bending test was equal to 100 mm. The results of basic material properties show influence of PVA. Adding PVA up to 4.0 wt. % of mixture worsens the workability of the fresh mixtures by reducing the spillage. As a result, there is an increase number of technological pores and thus the total porosity, which results in a reduction of bulk density (Tab. 2).

Tab. 2: Comparison of the material properties (with standard deviations).

Samples	Spillage [mm]	Bulk density [kg/m^3]	Total porosity [-]	Shrinkage (after 24 hours)
D/W 0.0 %	240 ± 5	1820 ± 40	0.24 ± 0.02	0.18 ± 0.01
D/W 1.4 %	230 ± 4	1620 ± 35	0.29 ± 0.01	0.13 ± 0.02
D/W 2.8 %	190 ± 5	1590 ± 38	0.31± 0.02	0.12 ± 0.01

D/W 4.0 %	179 ± 4	1540 ± 31	0.33 ± 0.01	0.09 ± 0.01
D/W 5.6 %	136 ± 3	1663 ± 50	0.27± 0.01	0.24 ± 0.01

Fig. 1 presented results of flexural strengths. The effect of PVA quantity is clearly visible for the dry samples (D), a value of the dry samples with 5.6 wt. % of PVA is two time higher that ones for the reference samples without PVA. Decrease of flexural strength corresponded with lower quantity of PVA for the other values. The different results were obtained for the wet samples, where the values of the reference samples and the samples with 5.6 wt. % are similar.

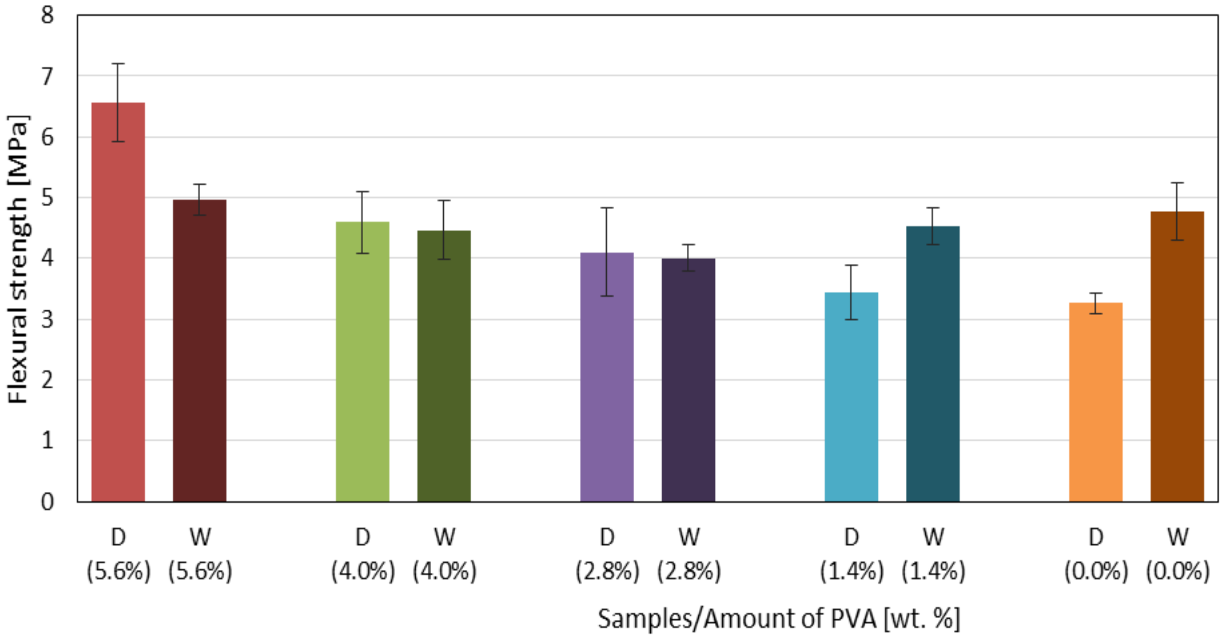

Fig. 1: Comparison of flexural strength (with standard deviations).

Conclusions

This work is focused on influence of PVA on flexural strength of cement composites. The resulting cement composites was composed of Portland cement, recycled concrete powder and PVA with different amount (namely 0, 1.4, 2.8, 4.0 and 5.6 wt. % of cement and recycled concrete). Based on the results it can be concluded that:

- PVA solution resulted in a decrease of the workability of fresh mixture because of its high viscosity,
- increasing the amount of PVA up to 4.0 wt. % resulted in increasing porosity. Due to the increase of porosity was reduced the bulk density,
- the value of flexural strength of the cement composites increases with increasing the volume of the PVA despite the higher porosity in the case of dry samples (D),
- the condition of curing under water level had bad influence on the value of flexural strength of cement composites with PVA,
- the best average value of flexural strength had samples with 5.6 wt. % PVA at standard laboratory conditions, namely 6.6 ± 1.1 MPa.

In the future, we will focus the possibility of involvement of PVA and recycled concrete powder in the hydration process, to follow the studies of e.g. [5]; and PVA will be tested for modification of historic mortars [9] or gypsum composites [10] in solid form or as an alternative as nanotextile [11, 12].

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