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EFFECT OF POLYPROPYLENE FIBER ADDITION ON MECHANICAL PROPERTIES OF CONCRETE BASED ON PORTLAND CEMENT

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Abstract

In this work results of poly(propylene) fibers (PP), from recycling process, added into concrete mixture based on portland cement was characterized. The main purpose of this research was to identify direct influence of the fibers addition on the concrete mechanical strength. The recipe of the concrete was prepared using three types of aggregates with different grain size: 0.125–0.250, 0.250–0.500 and 0.500–1.000 mm, deflocculant based on polycarboxylates, water and portland cement (42.5 MPa). To identify structures of the researched samples and fibers light microscopy (LM) observation was performed. Basic properties of concrete mixture were defined by slump cone test and setting time. Mechanical properties such as compressive strength and bending test after 1, 7, 14 and 28 days were characterized. Obtained results were compared with mixtures without fibers modifications. Study was proven that all chosen fibers from recycled origin revealed increased effect on final mechanical properties of concrete and are very perspective for future application in concrete technology.

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Introduction

Negative features of traditional concrete can be eliminated by using dispersed fibers in a concrete mix. Fibers after mixing and binding processes with the concrete form "fiber-concrete composite" with tensile strength and fatigue resistance higher than in traditional concrete (SONG et al. 2005, p. 1546–1550). Concrete provides adequate compressive strength, stiffness of the composite. Fibers provide protection against corrosion, increase tensile strength and reduce shrinkage that causes cracks in the concrete. Both elements complement each other. Due to the application and properties of the composite, fibers were divided into three groups: polymeric (polypropylene), steel and glass and carbon fibers (BANTHIA, GUPTA 2006, p. 1263–1267. KAKOOEI et al. 2012, p. 73–77).

The smallest and lightest are polypropylene fibers, usually added to concrete mix in amount of about 0.6 kg/m^3. Due to dispersion of the polymeric fibers, increase of the composite strength in all directions is observed. Addition of the polymeric fibers causes reduction of the contraction of the concrete, especially during its first binding phase (LIMA et al. 2016).

Steel fibers are still the most common used fibers in concrete industry. They cause increase of the tensile and fatigue strength of the hardened composite. They are typically dosed in an amount from 15 kg/m^3 to 40 kg/m^3 of a concrete mixture. Steel fibers also limit shrinkage in concrete but only when dosing values is low (15 kg/m^3). It is also recommended to add polypropylene fibers to steel fibers in the concrete mixture in order to reduce cracks on the concrete surface. Large amount of fibers per cubic meter, in some cases, could replace classical reinforcement almost completely. Steel fibers can also be classified due to their shape and length. Thus, straight fibers, corrugated, curved and in the shape of a letter resembling the letter C or Z are found (CHOUMANIDIS et al. 2016, p. 266–277. SMRKIĆ et al. 2017, p. 893–905).

Macropolymer fibers are in a direct competition with steel fibers. They are characterized primarily by a higher tensile strength, less dosing to the concrete mix and the fact that they do not corrode. Currently, these fibers are produced from various polymers, including polyacrylate, polyamides, polyesters, polyethylene and other plastics (GLID et al. 2018, p. 12641–12650).

Fiber dosing value has a significant impact on the behavior of the concrete mix. The fibers can cause a reduced workability of the concrete mixture. Therefore, the entire mixture should be designed optimally and take care on the details. Due to the different shape and slenderness of the fibers, they can cause the formation of undesirable "hedgehogs" structure in a concrete mixture. To avoid it, the fibers should be added slowly to the concrete and mixed longer. After adding more than 4% of the weight of fibers to the concrete mixture, it can be concluded that these mixtures are already unstructured. Concrete mixtures based on fibers can be only made in concrete containers, because such mixtures are almost impossible to pump (DINAKAR et al. 2013, p. 215–223, CENTONZE et al. 2015, p. 121–125, ZHANG et al. 2018, p. 57–65).

In conclusion, the use of fibers to the concrete has several advantages in reinforcement of the concrete composites, but due to the lack of the full experimental research of their influence on the properties of the composite in-depth study are necessary. Two types of recycled poly(propylene) fibers (with surface modification – grey fibers and without modification only after cutting process – green fibers) were used in the work and their influence on the final properties of ready concrete samples was analyzed.

Materials and methods

This research results present the influence effect of two new poly(propylene) fibers (PP) from waste material on final properties of the composite.

The basic parameters of poly(propylene) fibers – morphology, thickness, circumference, length were analyzed by digital light microscope (Olympus LEXT OLS4100).

Concrete mixtures were fabricated by mechanical mixing process of portland cement, quartz sand, water and fibers in amount of 0.5 wt.% of cement. Fibers were added at the end of the process of mixing. The recipe includes three parts of aggregates with different grain size: 125–0.250, 0.250–0.500 and 0.500–1.000 mm. Mixing process was lasted for 5 min using mechanical mixer (100 RPM) in lab condition at 21°C and 50% of humidity. After that the concrete mixtures have been transported into steel forms and left for the curing process (28 days).

Setting time was measured used Vicat's machine. Slump cone test was calculated according to PN-EN 12350-2: 2011 standard.

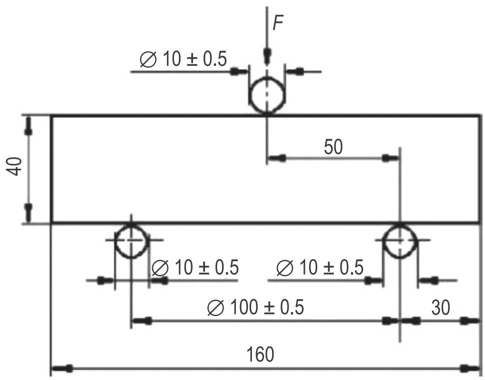

Fig. 1. Sample testing scheme of bending strength

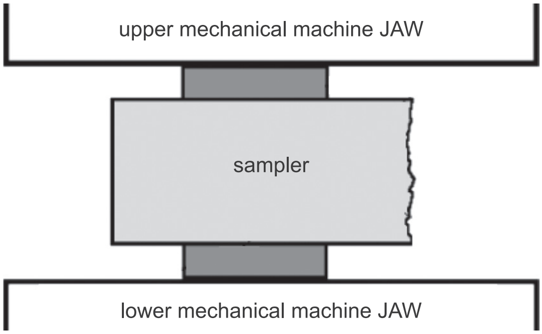

Fig. 2. Sample testing scheme of compressive strength

The measurement of the mechanical strength such as bending test and compressive strength was analyzed by Zwick machine on 40×40×160 mm samples after 1, 7, 14 and 28 days of curing process (Fig. 1, 2) using 10 samples for each test. After bending strength compressive strength was performed.

Results and discussion

Figures 3 and 4 present the morphology of used fibers for concrete mixtures preparation. Presented images show two different structures of chosen fibers. One of them (grey) was modified into the extruder and the second one was without modification. The surface modification was used to increase the strength effect of the fibers addition. Irregular surface probably provides better anchoring effect into the concrete mass. After extruder modification the fibers exhibits more than usual stiffness. The second fiber comes from cutting process of waste

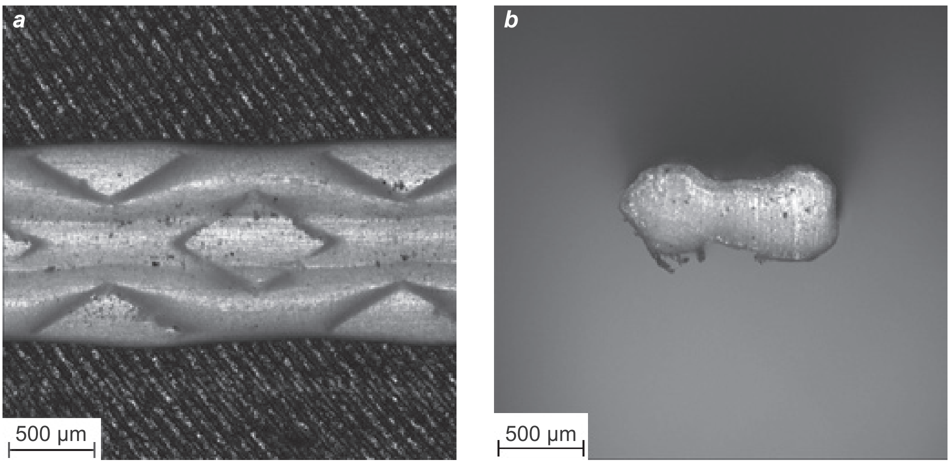

Fig. 3. Light microscope images of PP grey fibers: *a* – surface, *b* – cross section

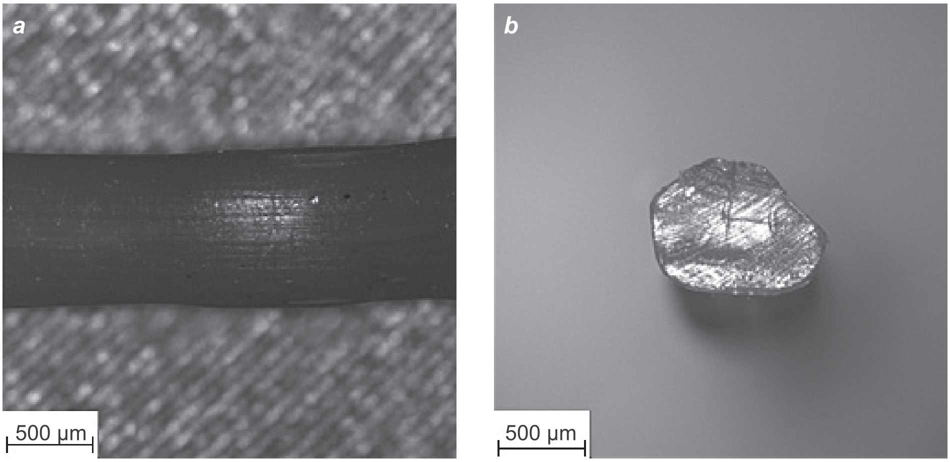

Fig. 4. Light microscope images of PP green fibers: *a* – surface, *b* – cross section

material. Both types of fibers are chemically identical, and come from with the same granulate product of PP. All tested fibers do not create agglomerates and they are easy to mix.

Table 1 shows the basic parameters of the researched fibers. Obtained results present that PP grey fiber exhibits higher values also in thickness and circumference parameters in comparison to the PP green fibers. The length of the both fibers is very similar, and it is approximately 31 mm.

Table 1

Basic properties of researched fibers

Fiber	Thickness [μm]	Circumference [μm]	Length [mm]
PP grey	1,146.6 ±5	566.5 ±5	31.2 ±0.5
PP green	888.9 ±5	485.2 ±5	30.9 ±0.5

Distribution of initial and final setting time was presented on Figure 5. Significant changes between reference sample and sample with added new poly(propylene) fibers were not observed. The setting time is very similar for all samples. Initial time is almost 180 min. and final time is equal 240 min.

The results of the bending test were shown on Figure 6. After first day of curing process sample based on PP grey fibers exhibits the highest value of bending force – 2.5 kN. However, on the next day of measuring the highest values were noted for PP green samples. In the last day of testing (28 day) this sample indicate 33% more strength than PP grey samples and 72% more than reference sample.

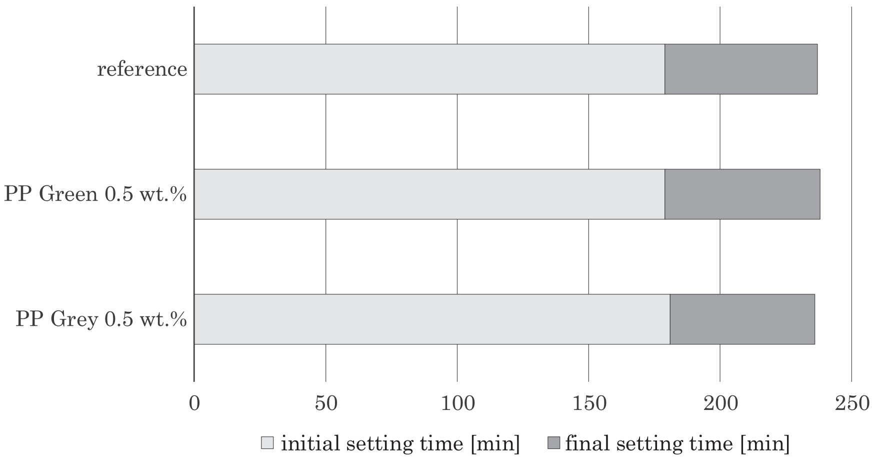

Fig. 5. Setting time distribution of tested mixtures

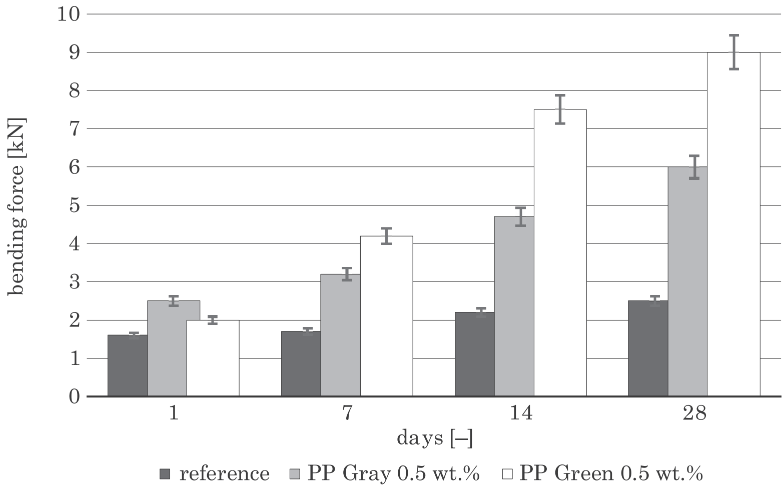

Fig. 6. Bending force distribution of concrete mixtures after 1, 7, 14 and 28 days of curing process

Compressive strength distributions of the researched samples were shown on Figure 7. It was noted that the PP green sample exhibits the highest values of compressive strength after all days of testing. Only measure after 7 days revealed the same value. The increasing effect was observed. On the 28 days of curing, compressive strength at level of 72 MPa was noted for PP green sample.

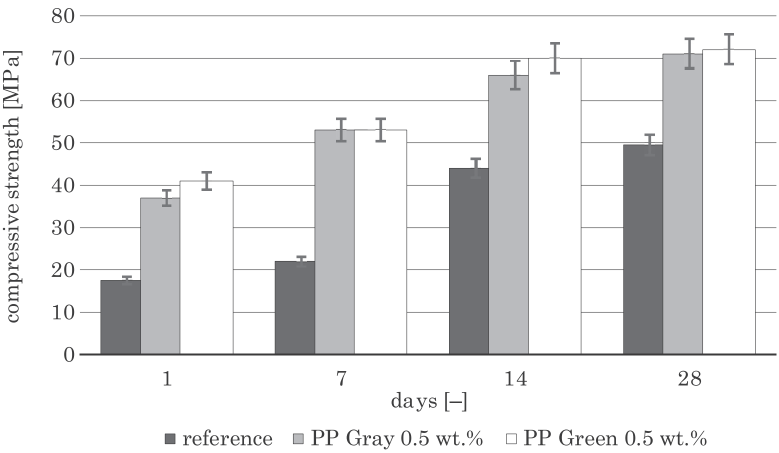

Fig. 7. Compressive strength distribution of concrete mixtures after 1, 7, 14 and 28 days of curing process

Conclusions

According to the assumptions, the final influence of the addition of new poly(propylene) fibers from the waste materials to the matrix of concrete on the composite properties was proven and characterized in this paper. Addition of the fibers significantly improved the plasticity of the composite. Additionally, final compressive strength of the composite also increased in reference to pure concrete after all days of testing. Final mixture was not problematic in process of mixing and could be prepared in environment condition. This study proven that it is possible to produce new concrete composite using waste materials and obtain higher values of final properties. Additionally, replacement of a cement addition on the recycled waste fiber are more environmentally friendly and provide less of CO_2 gases emitted (produced in the process of cement fabrication) in to the atmosphere.

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