REINFORCEMENT OF CONCRETE WITH FIBRILLATED POLYPROPYLENE FIBRES

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Abstract

Fibrillated polypropylene fibres were produced with different formation parameters. The morphology of fibres and their properties were examined. Fibres characterised by the best mechanical parameters were selected and used for the reinforcement of concrete. The workability of the fresh concrete was investigated. With the addition of fibres the increase of the air content and the consistence of the fresh concrete was observed. Subsequently the compressive strength and freeze resistance of the reinforced concrete were examined. Additionally, the studies of water absorbability and the morphology of the concrete surface were performed. It was stated that before freezing the fibres have relatively little effect on the compressive strength of the concrete. The effect the fibres have on the concrete is revealed after freezing and thawing cycles. For reinforced concrete lower reduction of the compressive strength is observed. Reinforced concrete has lower water absorbability. In contrast to non-reinforced concrete, on the surface of the fibre-reinforced concrete microcrackings are not visible.

Keywords: fibrillated polypropylene fibres, mechanical parameters, reinforced concrete, microcrackings

1. Introduction

The application of fibres in improving the mechanical properties of construction materials has been known for a long time. In the beginning of the XX century the first attempts of reinforcing the concrete with steel fibres were undertaken. Few decades later natural and chemical fibres for reinforcement of concrete were applied. The literature on the subject describes the successful attempts of applying various natural, as well as glass, carbon, polyaramide and other typical synthetic fibres [2-5].
From the group of synthetic fibres the polypropylene fibres are the subject of a particular interest. Polypropylene fibres posses low density, high chemical and biological resistance, do not absorb water during the mixing of mortar and do not corrode during the utilisation of concrete constructions.

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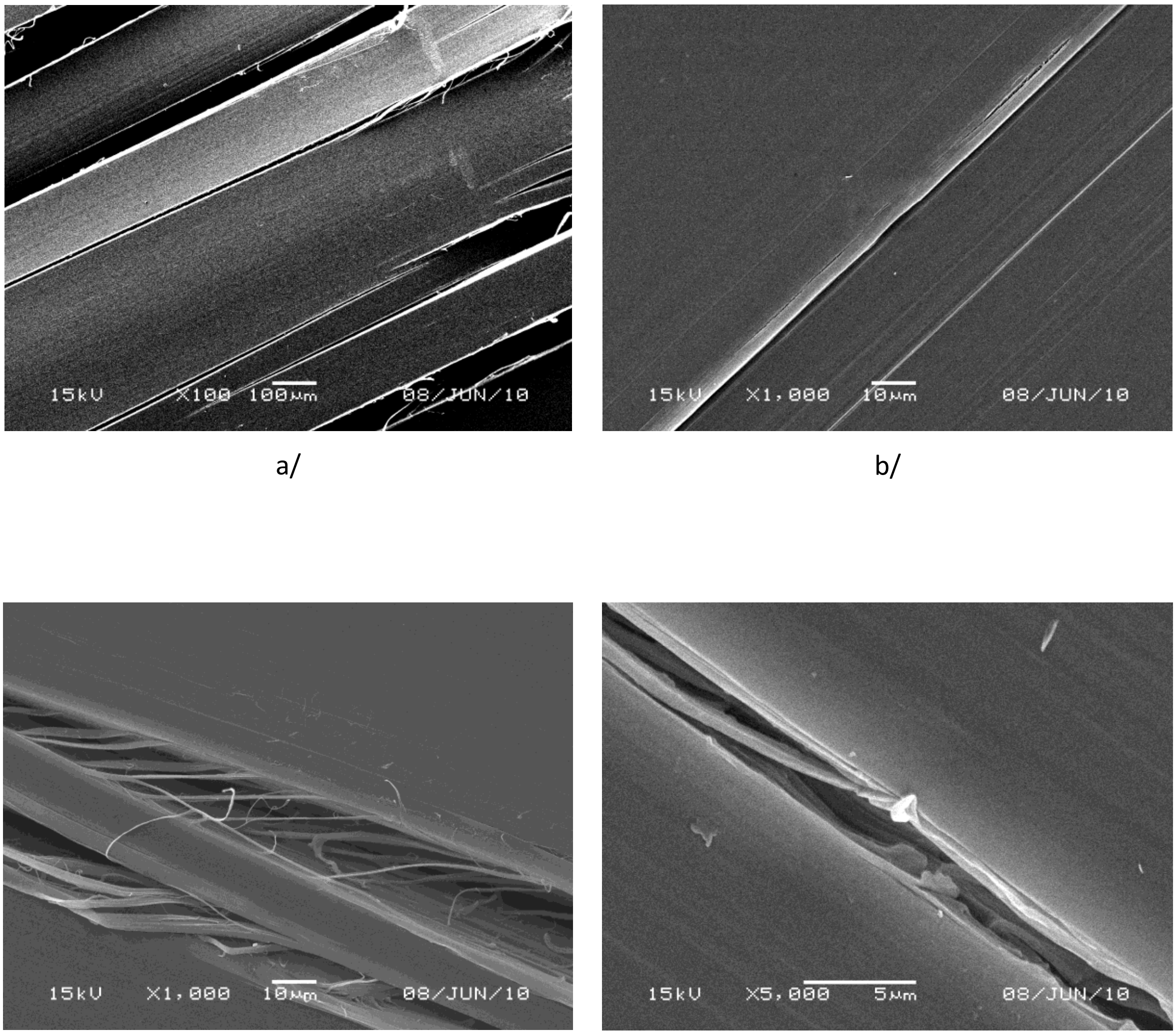
For the concrete reinforcement staple mono and multifilament, as well as fibrillated polypropylene fibres can be applied. Dosage of the fibres, their geometry, as well as the surface and mechanical properties affect the effectiveness of reinforcement [3,4].
Fibrillated fibres seem to have a distinct advantage over the monofilament type fibres. During mixing of concrete fibrillated fibres form an open network, which will increase their specific surface area. As the result the adhesion of fibres to the cement, matrix is considerably improved.
The formation of fibrillated polypropylene fibres is a multistage process and involves melt extrusion through a flat or an annular die, film solidification through water quenching, uniaxial stretching of the film, heat stabilization, cutting the film into narrow tapes, splitting the tapes into a finer fibrous material and final take-up. Each step has a great influence on the final mechanical parameters of the fibres.
The paper presents investigations on the application of fibrillated fibres for the reinforcement of concrete. The fibres were produced with different formation parameters and their morphology and mechanical properties were examined. Selected fibres were used for the reinforcement of concrete. The workability of the fresh concrete, as well as the compressive strength and freeze resistance of the reinforced concrete were investigated.

2. Experimental

Fibres were produced in industrial conditions in Bezalin SA (Bielsko-Biala, Poland) from the commercial polypropylene resin Moplen HP 456J (Orlen Polyolefins) characterised by melt flow index 3.4 g/10min with addition (2%) of polyethylene Bralen FB 2- 30 (Slovnaft Petrochemicals).
Polypropylene films were extruded through a flat die into water and then were cut into narrow strips. After drawing and heat stabilisation, the strips were locally cut with a needle roller and split with the final stretching unit. The fibres with the linear density 1000 tex were produced. Two draw ratios: 8.66 and 9.83 and three velocities of the needle roller: 150, 180 and 200 [m/min] were applied.
The morphology of the fibres was studied using a scanning electron microscope Joel JSM 5500 LV. Observations were carried out for the fibres sputtered with gold in Jeol 1200 ionic sputter. The mechanical parameters of the fibrillated fibres: tenacity, elongation at break and Young modulus were determined. The measurements were performed according to PN- EN ISO 5079 standard using a tensile machine INSTRON 1026.
Selected fibres with the best mechanical parameters were cut into segments with the length of 19 mm and were mixed with the concrete in proportion 0.9 kg of fibres per cubic meter of concrete. Workability of the fresh concrete, density and air content were investigated according to the Polish standards PN-EN 12350-2:2001, PN-EN 12350-6:2001 and 12350-7:2001. The compressive strength of concrete was determined before and after 150 freeze-thaw cycles according to the Polish norm PN-EN 12390-3-2002. The investigations of water absorbability were performed according to the Polish norm PN-88/B.

3. Results

Fig.1 presents microphotographs of the surface of the polypropylene fibres. Fig.1a presents longitudinal cuttings on the polypropylene strips produced by the needle roller mounted before the final drawing unit. At higher magnifications on the surface of the strips the fibrillar structure is clearly visible (Fig. 1b). Fibrils are closed packed and well oriented along the strips. The diameter of the fibrils equals ca. 0.1 μm.



a/ b/ c/ d/

Fig.1. Surface morphology of fibrillated fibres; a/ longitudinal cuttings of polypropylene strips, b/ fibrillar structure of the strips, c/ links between adjacent fibres, d/ splitting of fibres

After cutting the strips with the needle roller and drawing, the splitting of the fibrils is observed. As the result, strips partially disintegrate into fibres connected together in a network-like structure. Between the adjacent fibres many links are still observed (Fig.1c). By intense drawing the number of links between the fibres decreases (Fig.1d).

Tab.1. presents mechanical parameters determined for investigated fibres.

Tab.1. Mechanical parameters of investigated fibres.

Draw ratio	Needle roller velocity [m/min]	Tenacity [cN/tex]	Elongation at break [%]	Young modulus [cN/tex]
8.66	150	37.5	32	1.92
	180	36.9	28	1.95
	200	34.7	30	1.89
9.83	150	38.0	21	3.2
	180	37.0	23	2.9
	200	37.0	23	2.7

The tenacity of fibres comprises in the range 34 ÷ 38 [cN/tex]. For the fibres drawn at ratio 9.83 the tenacity is slightly higher. For both series of fibres, drawn at 8.66 and 9.83, the largest tenacity exhibit the fibres produced at the smallest needle roller velocity 150 [m/min]. With the increase of roller velocity the tenacity of fibres slightly decreases. The breaking elongation of fibres varies within the range 21 - 32 %. In comparison to the fibres drawn at 8.66, elongation at break for the fibres drawn at 9.83 is higher. For both series of fibres elongation at break does not change with the change of the needle roller velocity. The Young modulus for examined fibres changes within the range 1,9 - 3,2 [cN/tex]. Fibres drawn at lower ratio 8.66 possess lower value of the Young modulus, which is independent of the needle roller velocity. For the fibres drawn at ratio 9.83 the value of Young modules is higher. The fibres produced at low needle roller velocity possess the highest value. With the increase of the roller velocity the Young modulus decreases.

The highest tenacity and the highest Young modulus possess fibres produced at draw ratio 9.83 and needle roller velocity 150 [m/min]. These fibres were selected for further investigations. The fibres were cut into segments and then were mixed with concrete.

Tab. 2 presents determined parameters of the fresh concrete.

Tab.2. Parameters of fresh concrete for samples prepared with and without fibres.

Sample	Workability [cm]	Density [kg/m^3]	Air content [%]
without fibres	13	2329	1.9
with fibres	10	2315	2.3

The workability of the fresh concrete with fibres is lower in comparison to the sample without fibres. Addition of fibres results in a decrease of the concrete density and an increase of the air content.

Tab.3 presents parameters determined for the concrete reinforced with fibres. For comparison, the values obtained for unreinforced samples are presented.

Tab.3. Parameters of concrete for samples unreinforced and reinforced with fibrillated fibres.

Sample	Compressive strenght before freezing [MPa]	Compressive strenght after 150 freeze-thaw cycles [MPa]	Strenght decrement [%]	Water absorbability
without fibres	45.4	33.3	26.7	6.5
with fibres	43.7	35.7	18.3	4.7

The compressive strength of the unreinforced concrete equals 45.4 [MPa]. For the concrete reinforced with fibrillated fibres the compressive strength is minimally lower and equals 43.7 [MPa]. After freeze-thaw treatment the compressive strength of the concrete changes significantly. For the concrete without fibres the compressive strength drops to 33.3 [MPa] and for the concrete with fibres to the 35.7 [MPa]. It means that for the reinforced concrete the strength decrement is much lower. After freezing and thawing cycles the water absorbability of the reinforced concrete is considerably lower.

After freezing on the surface of the unreinforced concrete many cracks are observed. In contrast, on the surface of the fibre-reinforced concrete microcrackings are not visible.

5. Conclusions

The mechanical parameters of fibrillated polypropylene fibres are strongly influenced by the formation parameters. High draw ratio and low needle roller velocity promote formation of fibres with high tenacity and high Young modulus. By optimising the formation parameters, the appropriate fibres for the reinforcement of concrete can be produced. Fibres added to the concrete improve the parameters of a fresh concrete. Fibres have a relatively little effect on the compressive strength of concrete before freezing. The beneficial effect of fibres is revealed after freezing and thawing cycles. For reinforced concrete lower reduction of the compressive strength is observed. The reinforced concrete has lower water absorbability. Fibrillated fibres significantly reduce propagation of cracks.

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4. References

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