

Article

Mortars with Polypropylene Fibers Modified with Tannic Acid to Increase Their Adhesion to Cement Matrices

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Featured Application: Fiber concrete, mortar and other cementitious composites reinforced with polypropylene macrofibers.

Abstract: The presented research's main objective was to evaluate the possibility of improving the adhesion between polypropylene fibers and mineral matrices in cementitious composites by modifying the fibers' surface with tannic acid (TA). This modifier was previously used for polyethylene fibers only. Cement mortar containing modified polypropylene fibers and mortar containing unmodified fibers were tested. The physical and mechanical properties (apparent density, compressive strength, flexural strength and modulus of elasticity) were determined, and the fibers' morphology after the specimens' destruction was observed. No adverse effect of the modification was found. The elastic modulus was 6% lower after 28 days, enabling the formation of a less stiff composite material. The integrity of the specimens after mechanical damage was improved, confirming the increased adhesion between the polypropylene fibers and the hardened cement paste. The results of the introductory tests are promising; however, further research is needed in the field.

Keywords: adhesion; cementitious composite; fiber-reinforced concrete; modification; polypropylene fibers; tannic acid



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1. Introduction and Scope

Fiber concrete (or fiber-reinforced concrete) is a type of concrete that contains fibers to enhance its mechanical strength and resistance to cracks and, generally, its durability [1]. The fibers are made mainly of two materials, steel and synthetic polymers (e.g., polypropylene, polyethylene or polyamide); however, other types of fibers are also used, like cellulose, glass, carbon or basalt. The effectiveness of fibers in concrete depends on their strength, shape and dimensions, but also their content, dispersion and adhesion to the cementitious matrix. The last issue is crucial in the context of using polymer fibers, the adhesion of which to mineral matrices is much lower than those made of steel due to their smooth surfaces [2–4]. Therefore, to fully exploit the potential of polymer fibers, it is necessary to improve their adhesion and compatibility with cement matrices.

1.1. Polymer Microfibers and Macrofibers Used in Concrete and Other Cementitious Materials

Generally, there are two basic types of polymer fibers used in ordinary concretes and other concrete-like materials with cementitious matrices: micro- and macrofibers.

Microfibers are fibers with very small cross-sections (diameters of several to a dozen micrometers) and lengths usually not exceeding 12 mm (see Figure 1). The dosing of such fibers is 0.2–2.0 kg per 1 m³ of the composite, depending on the intended use. Microfibers are intended mainly for non-structural applications and can be considered for microreinforcement, which reduces plastic shrinkage and prevents the appearance of microcracks in cement matrices in the early stage. It is advisable to use them in various composites (concretes; thin-layer screeds, including ones for underfloor heating and plastering; masonry

mortars; repair mortars; adhesives; insulating coatings; etc.), especially if they contain high-class Portland cements with high early strength, i.e., with an increased tendency to shrinkage and crack development, or, in general, in advanced cementitious matrices that are characterized by a refined microstructure and low porosity (e.g., a water/binder ratio lower than about 0.3). Due to their small size, microfibers can easily be evenly distributed in cement paste and create a spatial mesh that can additionally reduce water absorption and increase the water tightness and frost resistance of modified composites. The authors confirmed in previous research investigations [5] that it was possible to obtain a seamless polymer–cement insulating coating with polyacrylonitrile microfibers that showed excellent elasticity and water resistance and at the same time remained water-vapor permeable. Also, when mortars with PP microfibers (presented in Figure 1b) were tested, no negative impact on the mixes' consistency was observed, while hardened composites were characterized by assumed compressive strength and flexural strength. Therefore, it was not necessary to analyze or to improve the adhesion between the used microfibers and the composite matrices.

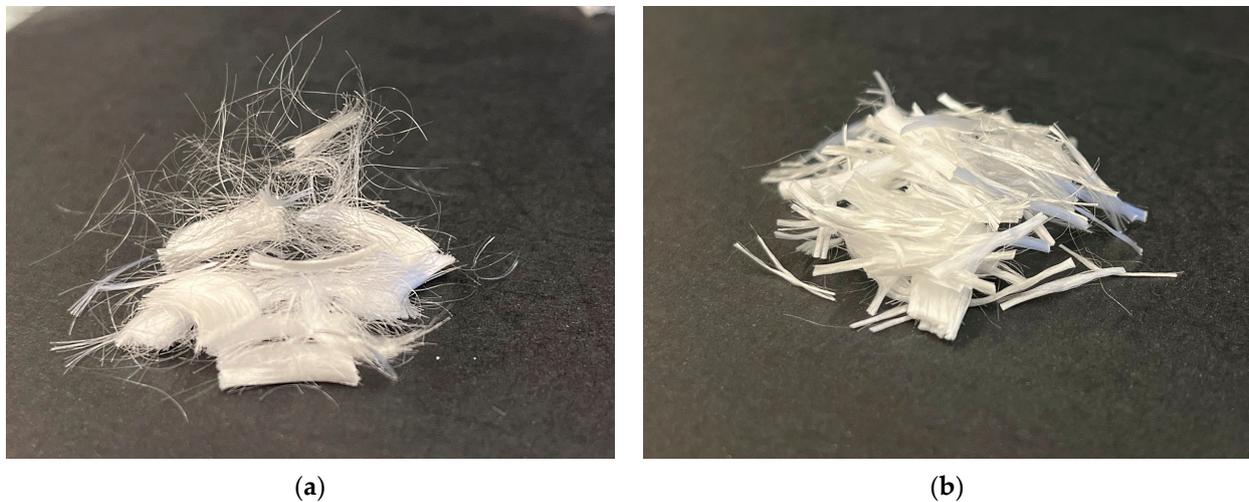


Figure 1. Commercial polypropylene microfibers of similar geometry (both with a length of 12 mm and a diameter of 18 μm) from different manufacturers: (a) fibers without an additional coating; (b) fibers additionally covered with a water-soluble coating.

The second type of polymer fibers used for concrete, i.e., macrofibers or structural fibers (sometimes referred to as “traditional fibers”), have much larger cross sections (diameters of 0.1 mm and more) and greater lengths. Bentur and Mindess [1] distinguished a third type of fiber, i.e., mesofibers, which have cross-sectional dimensions in the range of 0.1 to 0.3 mm; however, in most studies in the scientific and industrial literature and most technical data reports (including most of the mentioned references), fibers with such cross sections are classified as fine macrofibers. Unlike the situation with polymer micro-fibers, in the case of macrofibers made of polymers, the issue of adhesion is much more problematic. Polymer macrofibers are added to cementitious mortars and concretes (structural and non-structural) for several reasons:

- To reduce plastic shrinkage and the formation of microcracks in cement matrices;
- To increase the mechanical strength of composites (including flexural and tensile strength, as well as the level of fracture energy absorption and impact strength);
- To reduce the possibility of crushing and spalling at the edges of composite elements.

The positive effects of the presence of polymer macrofibers mentioned above are basically the same as the effects of steel fibers, but they cannot be treated as a direct replacement for steel fibers of the same geometry, mainly due to their much lower adhesion to cement binders.

The authors have reviewed the range of polymer macrofibers currently available on the Polish market and used in concrete production. The main commercially available polymer macrofibers are polypropylene, polyethylene and polyolefin copolymer fibers with lengths between 24 and 54 mm. Some fibers are crimped (Figure 2a) and others are twisted (Figure 2b) to provide better anchoring in cement matrices. However, despite these geometric adjustments, the adhesion of all polymer fibers to cement paste is much lower compared to steel fibers, and if the reinforced element is damaged, the polymer fibers can easily be pulled out from the matrix. The additional lengthening of fibers and increase in their cross-sections (and thus extension of the anchoring zones and the contact surfaces) do not significantly improve the integrity of the composites at failure [6]. A better solution seems to be the modification of polymer fibers in order to roughen their initially very smooth surface and to expand the contact zones with hardened cement paste. This can be achieved either by mechanical modification (the surface of the fibers is mechanically modified to create a rough texture by subjecting the fibers to abrasion or friction, e.g., by sanding) or chemical modification, including coating (i.e., applying chemical agents or rough materials onto the surface of the polymer fibers [6,7]) and chemical surface treatments (e.g., with acids [8,9]). Selected examples of chemical surface treatments for polymer fibers are given in the next section.

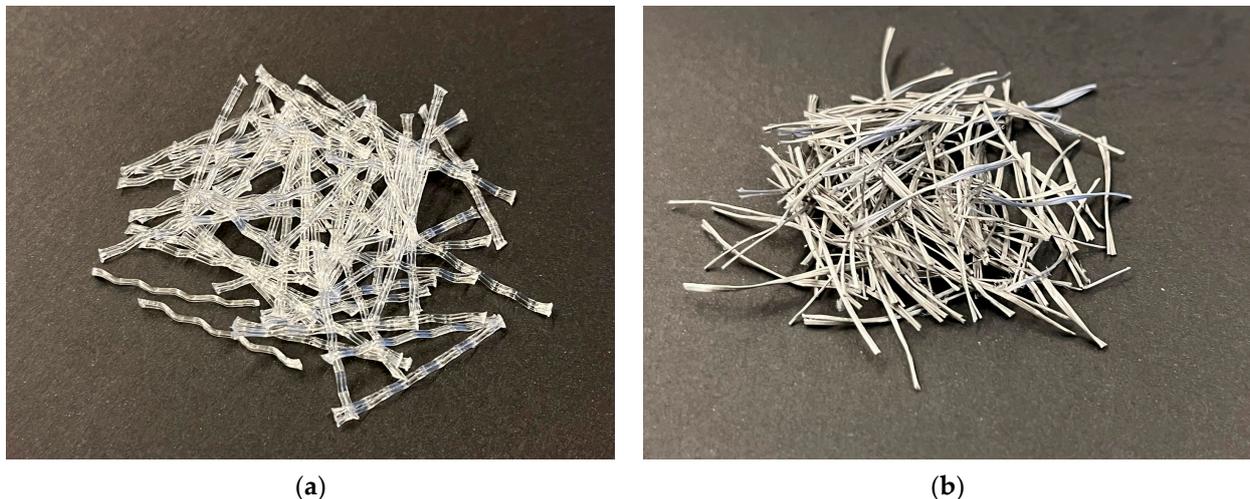


Figure 2. Examples of macrofibers with various geometries that are commercially available in Poland: (a) crimped polypropylene macrofibers (length of 25 mm); (b) polyolefin copolymer fibers twisted in bundles (length of 24 mm).

1.2. Chemical Surface Modification of Polymer Fibers—Selected Methods

The scientific and technical literature contains descriptions of numerous attempts to improve polymer fiber quality and durability by chemical modification. For instance, the authors themselves successfully performed the surface modification of fibers made from recycled PET with ethylene-vinyl acetate copolymer (EVA) [6] to prevent hydrolysis of ester linkages of poly(ethylene terephthalate) in the highly alkaline environment of fresh cement paste (for detailed information on PET degradation in alkaline environments, see also: Silva et al. [10], Pelisser [11] and Won et al. in [12]).

In the case of polypropylene fibers, Wiliński et al. [8] modified the fibers using chrome acid to roughen their surface, and they concluded that non-polar polymer surface oxidation could be an efficient way to improve the fiber-reinforced concrete mechanical properties. In the case of polyethylene fibers, Bashiri Rezaie et al. [7] applied the approach used earlier, among others, by Shanmugam et al. [4], Changani et al. [13] or Xi et al. [14], for other non-polar polymers to test the possibility of improving the adhesion between polyethylene fibers and cementitious matrix by modifying the surface of the fiber with polydopamine. Using dopamine through oxidative self-polymerization reactions applied by a simple water-

borne deposition process, which forms a thin reactive polymeric layer comprising hydroxyl and amino groups on diverse inorganic and organic substances [13,15], enabled imparting a hydrophilic nature of the modified polymer, thus increasing its surface polarity and hydrophilicity [16]. They concluded that by dopamine surface modification, it was possible to increase the tensile strength of polyethylene fibers, pull-out strength and interfacial shear strength, thus enhancing the bonds between the initially hydrophobic polymer fibers and cementitious matrix.

Recently, Bashiri Rezaie et al. [9] researched the possibility of improving the adhesion between PE fibers and cementitious matrix using tannic acid. They obtained promising results, showing that this method allowed them to chemically roughen the fiber surface (Figure 3) and significantly increase the energy required to pull the modified fibers out of the matrix compared to unmodified fibers. They experimentally scaled the modification method, using different sequences of adding chemical reagents to the modifying solution and using different exposure times of the fibers to the modifying medium (compare Figure 3b–d), to finally indicate the most effective procedure for modifying polyethylene fibers assuming 3-h immersion of fibers in tannic acid supplemented with selected additional modifiers.

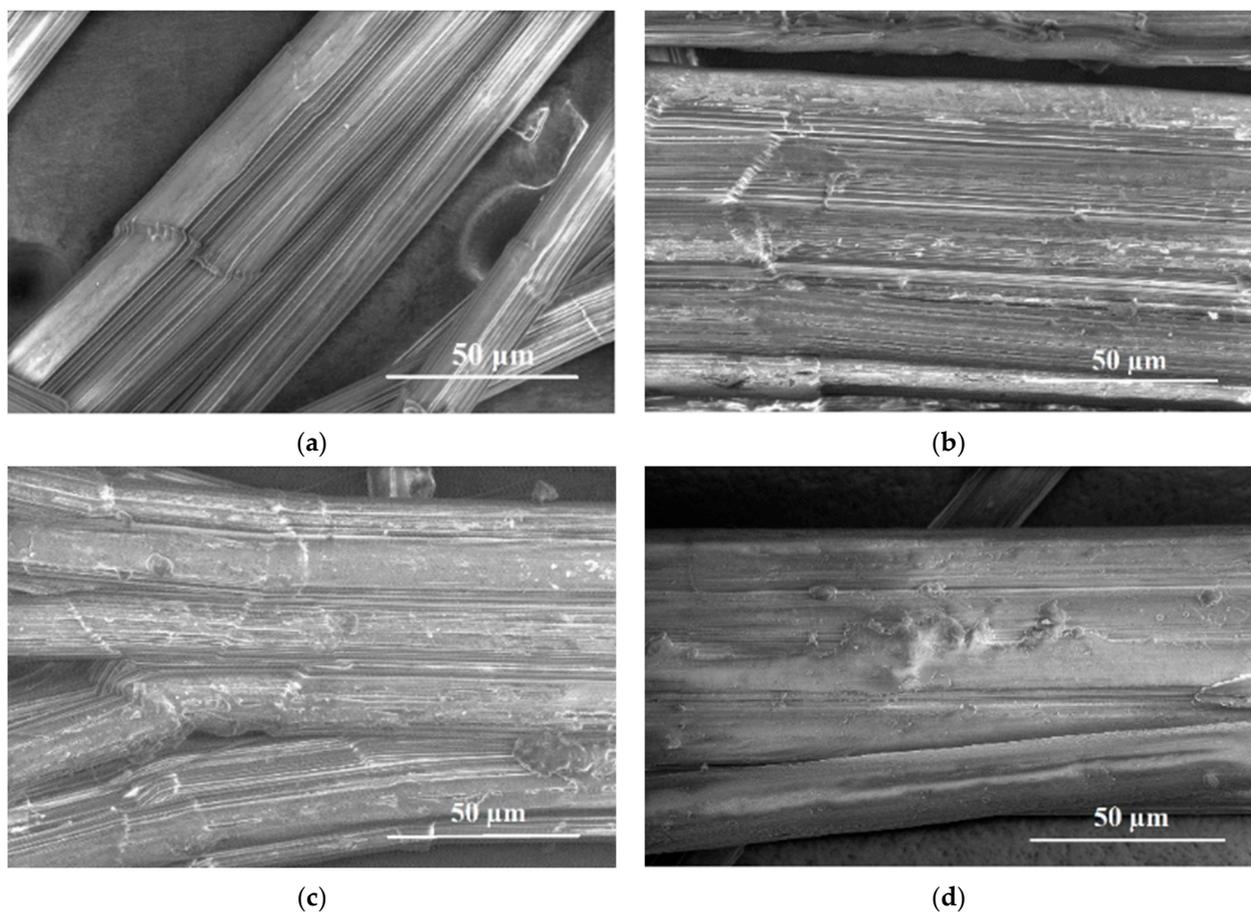


Figure 3. ESEM images of pristine PE fibers and various tannic acid-modified PE fibers: (a) pristine fibers; (b) fibers treated with tannic acid for 30 min; (c) fibers treated with tannic acid for 1 h; (d) fibers treated with tannic acid for 3 h (based on [9]).

The research by Bashiri Rezaie et al. [9] included only tests of individual fibers placed straight in a pure cement paste of high water/cement mass ratio of 2.0, i.e., a value several times higher than the ratio of actual scale composites used in construction. However, the authors decided to use the same chemical roughening mechanism in the context of polypropylene fibers available on the local market and check whether the method of rapid

modification with tannic acid would also improve the adhesion of PP fibers to the cement matrix with a water/cement mass ratio of 0.50 (recommended by EN 206 standard [17] for concretes working in the aggressive environments described by selected exposure classes—including the risk of carbonation, chloride aggression, freezing/thawing or mechanical friction), and whether it would affect (positively or negatively) the mechanical properties of mortars with such fibers.

While fibers of vegetable origins, like raffia, coconut or similar ones, can be successfully treated with alkaline products (e.g., sodium or potassium hydroxide), such modification is not recommended for polypropylene fibers. Synthetic polymers have weak alkali resistance; instead, they are acid-resistant [1]. As mentioned above, tannic acid was employed to modify polyethylene fibers [9]. The authors intended to assess whether this treatment method could also improve the performance of polypropylene fiber-reinforced cement composite.

2. Materials and Methods

2.1. Qualitative and Qualitative Composition of Tested Composites

The experiment involved comparing the behavior of surface-modified and unmodified polypropylene fibers applied to a composite with a cement matrix, which was then subjected to destructive mechanical tests. To eliminate the influence of other components on the test results, the composite selected as the base one, i.e., reinforced with dispersed reinforcement in the form of fibers, was the so-called comparative mortar, i.e., standard mortar made of high-early strength Portland cement class 42.5, i.e., CEMI 42.5 R (CEMEX, Chelm, Poland). The applied cement fulfilled the requirements of European Standards EN 197-1 [18] and EN 196-1 [19] in terms of the composition (at least 95% Portland clinker) and properties. The aggregate used in the mortars was standard sand (meeting requirements of EN 196-1). It was natural quartz sand with rounded grains, SiO₂ content of at least 98%, and grain size up to 2 mm. The size distribution of sand grains recommended by the EN 196-1 standard is presented in Table 1. The mixing water was tap water (meeting the requirements of EN 1008 [20]).

Table 1. Size distribution of standard sand grains according to EN 196-1.

Square Mesh Size, mm	2.00	1.60	1.00	0.50	0.16	0.08
Total residue on the sieve, %	0	7 ± 5	33 ± 5	57 ± 5	87 ± 5	99 ± 1

The applied fibers (presented in Figure 2a) were pure polypropylene macrofibers of a length of 25 mm (DIIF, Dnepr, Ukraine) designated to be used in structural concrete and mortars. Table 2 contains the basic physical properties of the fibers listed by the manufacturer [21]. The fibers were also characterized by high acid, alkali, and salt resistance and low thermal and electrical conductivity.

Table 2. Properties of macrofibers used in tested composites (manufacturer's data [21]).

Type of Polymer	Specific Gravity, kg/m ³	Melting Point, °C	Ignition Point, °C
Polypropylene (PP)	910	162	593

Standard EN 196-1 includes the composition of the standard mortar, which assumes a water/cement mass ratio of 0.50 and a cement/aggregate mass ratio of 1:3. For the experiment, both a standard mortar (without fibers) and mortars with an identical composition of essential components, but supplemented with chemically modified/unmodified fibers, were prepared. The amount of added fibers was based on the manufacturer's recommendations [21]. The manufacturer recommended dosing fibers in various amounts depending on the potential use of composites, i.e., 2–4 kg per 1 m³ of the concrete mix in the case of the production of industrial floors, screeds or sprayed concrete, and 2–6 kg per 1 m³ of the concrete mix in the case of concrete structural elements of residential and industrial

buildings. For the experiment, it was assumed that the fiber content would be close to the upper limit of the range recommended for structural concrete, i.e., 4.5 kg per 1 m³ of the mortar mix. The compositions of the tested mortars (calculated per mix following the standard procedure, assuming a specific gravity of 2650 kg/m³ for standard sand and of 3100 kg/m³ for the cement) are listed in Table 3.

Table 3. Composition of tested composites (by mass and volume).

No/Code	Cement		Water		Aggregate		Non-Modified Fibers		Modified Fibers	
	g	cm ³	g	cm ³	g	cm ³	g	cm ³	g	cm ³
1/SM							0	0	0	0
2/NM	450	145	225	225	1350	509	5	5.5	0	0
3/M							0	0	5	5.5

2.2. Procedure of Fiber Surface Modification with Tannic Acid

The surface modification procedure for polypropylene fibers used in the tested composites was adopted from the experiment described in [9] (among the methods described here, the variant that gave the best roughening effect was selected). The modification involved immersing clean fibers in a solution with the predominance of tannic acid, TA (CAS-Number: 1401-55-4), and the addition of sodium periodate, SP (NaIO₄, CAS-Number: 7790-28-5) and ethanolamine, EA (CAS Number: 141-43-5) for 3 h, and then washing and drying the fibers in ambient temperature for later use. All chemicals were delivered by Linegal Chemicals, Blizne, Poland. The modifying solution was prepared using 1 dm³ of distilled water, 4 g of tannic acid, 20 cm³ of ethanolamine, and 8 g of sodium periodate. The whole was mixed using a magnetic stirrer for about 15 min. The fiber modification procedure was as follows:

1. Inserting the fibers in the aqueous solution (TA + EA + SP) so that all of the fibers are immersed in the solution.
2. Keeping the fibers in the solution (covered container) for 3 h at ambient temperature.
3. Removing the fibers from the solution and rinsing several times in distilled water.
4. Drying the fibers at room temperature.

It is important to emphasize that the tannic acid was used only during the stage of the modification of the fibers (i.e., before the preparation of the concrete mix). The tannic acid had no contact with the concrete matrix and had no possibility of causing any chemical corrosion of the concrete.

2.3. Testing Methods

For all composites, the set of technical properties was determined as apparent density, flexural strength, flexural elastic modulus and compressive strength. The properties of mortars with fibers were determined after 7 and 28 days of curing. The standard mortar was tested after 28 days of curing (all specimens were demolded after 24 h after casting and then kept in the water in laboratory conditions). Flexural strength and flexural modulus were tested on a set of three standard specimens in the shape of beams of size 40 mm × 40 mm × 160 mm in the three-point bending test (using Instron 5567 electromechanical testing machine, Canton, OH, USA, Figure 4). The compressive strength was tested on the halves of the prisms remaining after the bending test (using Controls MC66 hydraulic press, Milan, Italy). According to EN 197-1, the applied method excludes the influence of the bending test on the compression test result—although the second test is performed on halves of the bent and broken prism specimen. The compressive force is applied to the specimen far enough away from the broken edge so that the intact part of the prism half is compressed. Apparent density was determined on the same specimens (mass of the specimens divided by their measured volume) just before the destructive tests, while the fractures of the specimens and fibers were visually observed using optical microscopes

(Biolux AL and Carl Zeiss Jena Neophot 32, Jena, Germany, with the Nikon D300 digital recording system, Tokyo, Japan) on the specimens after the tests.

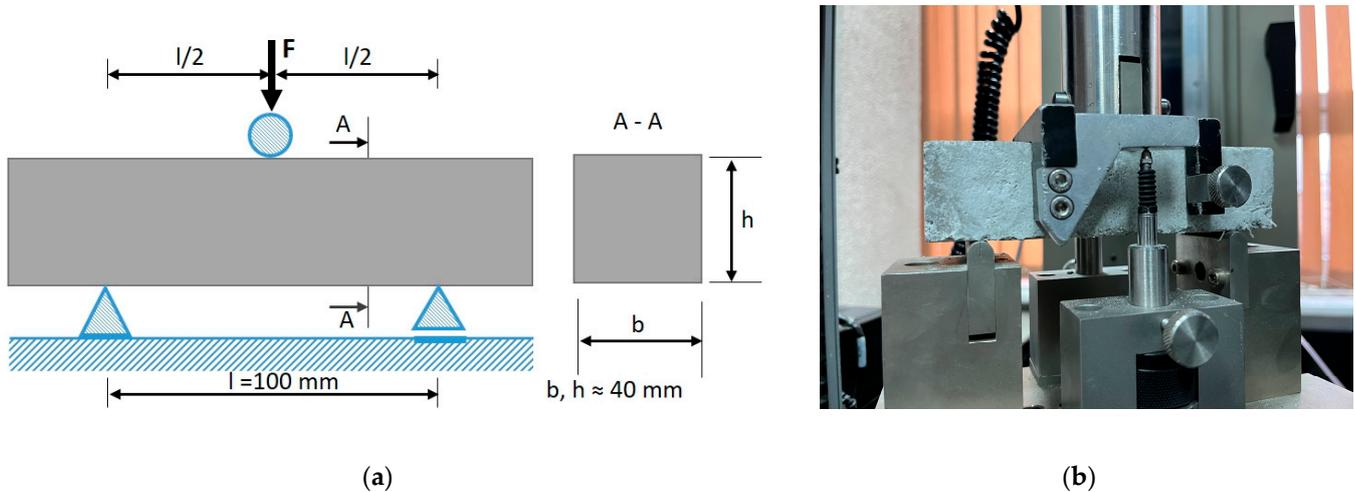


Figure 4. Flexural strength and modulus test performed on specimens in the shape of beams of size 40 mm × 40 mm × 160 mm in the three-point bending test acc. to EN 1015-11 [22]: (a) scheme of the test (specimen on two supports—one stationary, the other movable, so that the system is statically determinate, the force concentrated in the middle of the span); (b) specimen during the test in Instron 5567 electromechanical testing machine.

3. Results and Discussion

3.1. Physical and Mechanical Properties

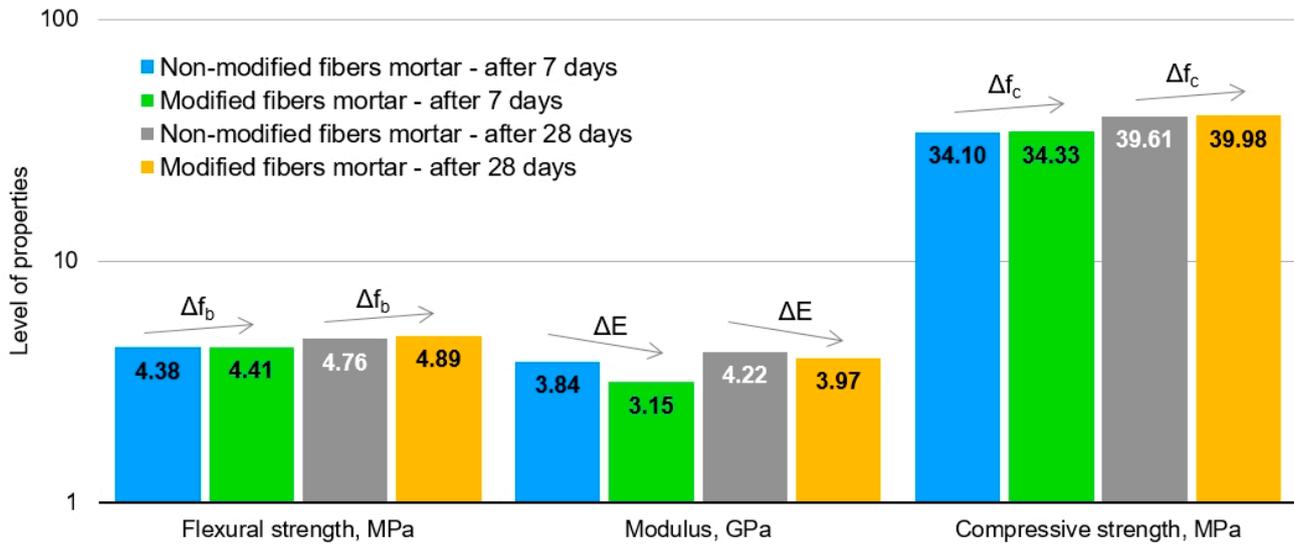
The results for apparent density (average and basic statistic parameters: standard deviation, SD and coefficient of variation, CV) of mortars with non-modified and modified fibers after 7 and 28 days and the density of the standard mortar after 28 days are given in Table 4. As expected, mortars with fibers made of polypropylene (with a specific gravity of 910 kg/m³—compare Table 2) were characterized by slightly lower (differences of up to 3%) apparent density compared to pure-mineral standard mortar. However, it is worth noting that the mortar containing non-modified fibers was characterized by a density with a 1.5 times higher coefficient of variation, while the mortar with fibers modified with tannic acid showed four times lower variability compared to standard mortar apparent density.

Table 4. Density of tested mortars: standard mortar (SM), mortar with non-modified polypropylene fibers (NM) and mortar with tannic acid-modified polypropylene fibers (M) determined after 7 and/or 28 days (SD—standard deviation, CV—coefficient of variation).

Composite Type	Density after 7 Days			Density after 28 Days			Relative Change to SM, %
	Mean, kg/m ³	SD, kg/m ³	CV, %	Mean, kg/m ³	SD, kg/m ³	CV, %	
Standard mortar (SM)	x	x	x	2261	37	1.6	-
Non-modified-fiber mortar (NM)	2186	25	1.1	2240	58	2.4	−0.9
Modified-fiber mortar (M)	2198	5	0.2	2198	8	0.4	−2.8

The results of the mechanical tests of mortars with fibers after 7 and 28 days are given in Figure 5. In the case of standard mortar, the results obtained after 28 days were as follows: flexural strength—7.46 MPa (on average) and compressive strength—45.16 MPa (on average), which stands in line with the expectation of standard EN 196-1 for such mortars with CEM I 42.5R binder (i.e., $f_{cm} \geq 42.5$ MPa). Both mortars with fibers had

lower strength after 28 days, and none exceeded 42.5 MPa in compressive strength. The difference compared to the standard mortar was 5.2–5.6 MPa (11.5–12.3% reduction). In the case of 28-day flexural strength, the difference compared to the standard mortar was more significant—reduction by approx. 35% was observed. However, such weakening of the cementitious mortar after adding polypropylene fibers is unsurprising, as the connection between the mineral matrix and the polypropylene fiber is weakened. Moreover, a slight correlation was observed between the decrease in mortar density and mechanical strength.



Property	Non-modified fibers mortar - after 7 days			Modified fibers mortar - after 7 days			Non-modified fibers mortar - after 28 days			Modified fibers mortar - after 28 days		
	Mean, MPa	SD, MPa	CV, %	Mean, MPa	SD, MPa	CV, %	Mean, MPa	SD, MPa	CV, %	Mean, MPa	SD, MPa	CV, %
Flexural strength, MPa	4.38	0.07	1.6	4.41	0.26	5.9	4.76	0.22	4.6	4.89	0.10	2.0
Modulus, GPa	3.84	0.05	1.3	3.15	0.03	1.0	4.22	0.08	1.9	3.97	0.81	20.4
Compressive strength, MPa	34.10	0.75	2.2	34.33	0.56	1.6	39.61	0.85	2.1	39.98	1.94	4.9

Figure 5. Mechanical properties of mortars with fibers after 7 days and 28 days of curing (SD—standard deviation, CV—coefficient of variation).

An interesting observation was that in each case—both in tests carried out after 7 days and after 28 days—higher flexural strength and compressive strength values were noted when using fibers modified with tannic acid. The differences were insignificant—they amounted to a maximum of 3%. However, authors expect that the effect of fiber modification on mechanical strength might be more remarkable in the case of composites of lower water/cement ratio and when adding plasticizing admixture that might provide a better coating of the fibers with a fluidized cement paste [23,24].

The crucial mechanical property when assessing the effect of introducing polymer fibers into the brittle mineral composite is the elastic modulus. When comparing the modulus of mortars with non-modified fibers and modified fibers, the latter was characterized by a significantly lower flexural elastic modulus. After 7 days of curing, the modulus of the mortar was lower by 700 MPa (18%), and after 28 days of curing, it was 240 MPa (6%). Thus, modification of fibers enabled obtaining less stiff composite material that can deform more easily under stress, making it more flexible.

3.2. Visual Inspection of Composite Fractures and Fibers

The polymer fiber modification was not expected to drastically improve the mechanical properties of the mortars, as such an effect would require changes in the composition of the

target composite. The main aim of the performed investigation was to determine whether the modified fibers were better anchored in the cement matrix, as that would be a sign that the tannic acid modification was effective in roughening the surface of the polypropylene fibers and improving their adhesion to the mineral matrix. Here, the visual inspection of the damaged specimens was helpful—visual inspection of the surfaces of scratched specimens (after bending), as well as the fractures of the broken specimens and the conditions of fibers themselves.

In Figure 6, one can see the comparison of the specimen's outer surfaces with both fiber variants after the flexural strength test. The test procedure did not assume loading the bending elements until the specimen wholly disintegrated, but until the stress dropped, which meant damage to the brittle material structure. In the case of standard mortar testing, as a result of exceeding the maximum stresses, the brittle cracking occurred in the area of the cementitious matrix and the aggregate–matrix interface, and the visible crack appeared, leading to the separation of the halves of the bent prism. However, in the testing of mortars with polymer fibers, the polymer fibers ensured the stability of the specimen even after the failure of the brittle matrix. Despite the destruction and significant decrease in the load capacity, the specimens retained their integrity. However, the nature of the destruction differed in the case of mortars with unmodified and modified fibers. The specimens with unmodified fibers were cracked across the entire thickness of the bent element (Figure 5, upper specimen). However, the specimens with modified fibers were only scratched (up to a maximum of 2/3 of the element thickness), and the crack width did not exceed 0.3 mm (thus fulfilling requirements of Eurocode EN 1992-1-1 [25] in terms of carbonation, chlorides other than from seawater and most of the chlorides from seawater exposure classes). Specimens with modified fibers clearly showed significantly improved integrity after failure.

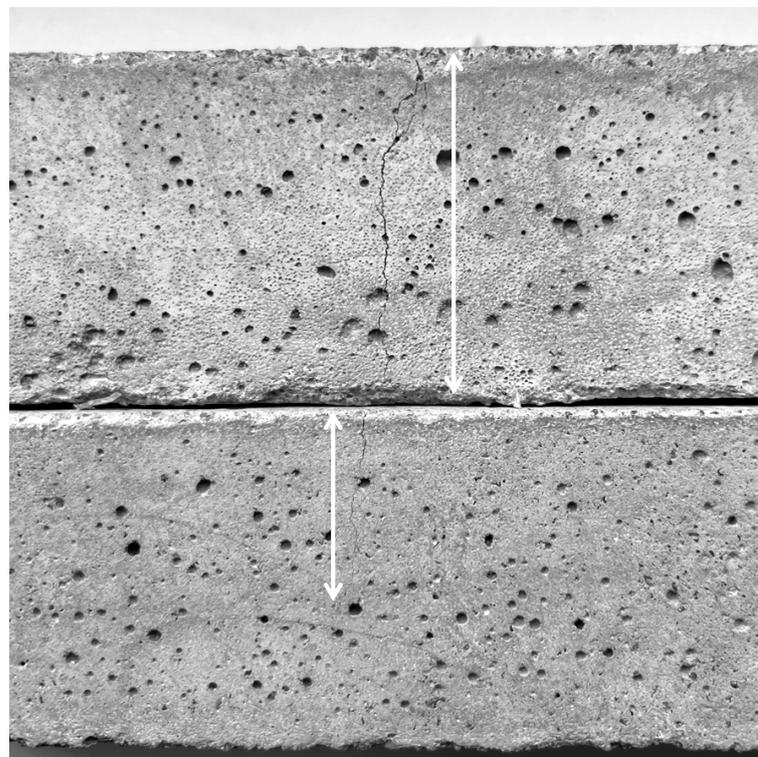


Figure 6. The outer surface and the mechanical damage (the length of the crack corresponds to the entire thickness of the specimen, i.e., 40 mm—see upper arrow) of the mortars with non-modified PP fibers (upper specimen) and PP fibers modified with tannic acid (lower specimen; crack range is 24.9 mm—see lower arrow) after flexural strength test (three-point bending test).

In order to measure compressive strength, which was the next phase of the experiment, the prisms had to be fully broken, which required additional loading of the specimens. After separating the prisms' halves, the fibers' fractures and condition were inspected. It was observed that the unmodified fibers were not broken but pulled out, often almost entirely, from the cementitious matrix (Figure 7a). Meanwhile, the tannic acid- modified fibers remained anchored in the matrix, and their breaks occurred close to the specimen fracture surface. Also, their ends were frayed, confirming breaking when their tensile strength was exceeded (Figure 7b). The above observation proves they better adhered to the matrix, which the authors attribute to the roughened surface of the fibers. The last conclusion was also supported by microscopic observations that showed that the surface of unmodified polypropylene fibers was smooth before their implementation into the mortar mix and after their pull-out from the broken specimen. The fibers subjected to the tannic acid modification showed a rough, more developed surface, i.e., predisposed to better adhesion to the cement paste, and a much more damaged surface after the destruction of the bent element (Figure 7c,d).

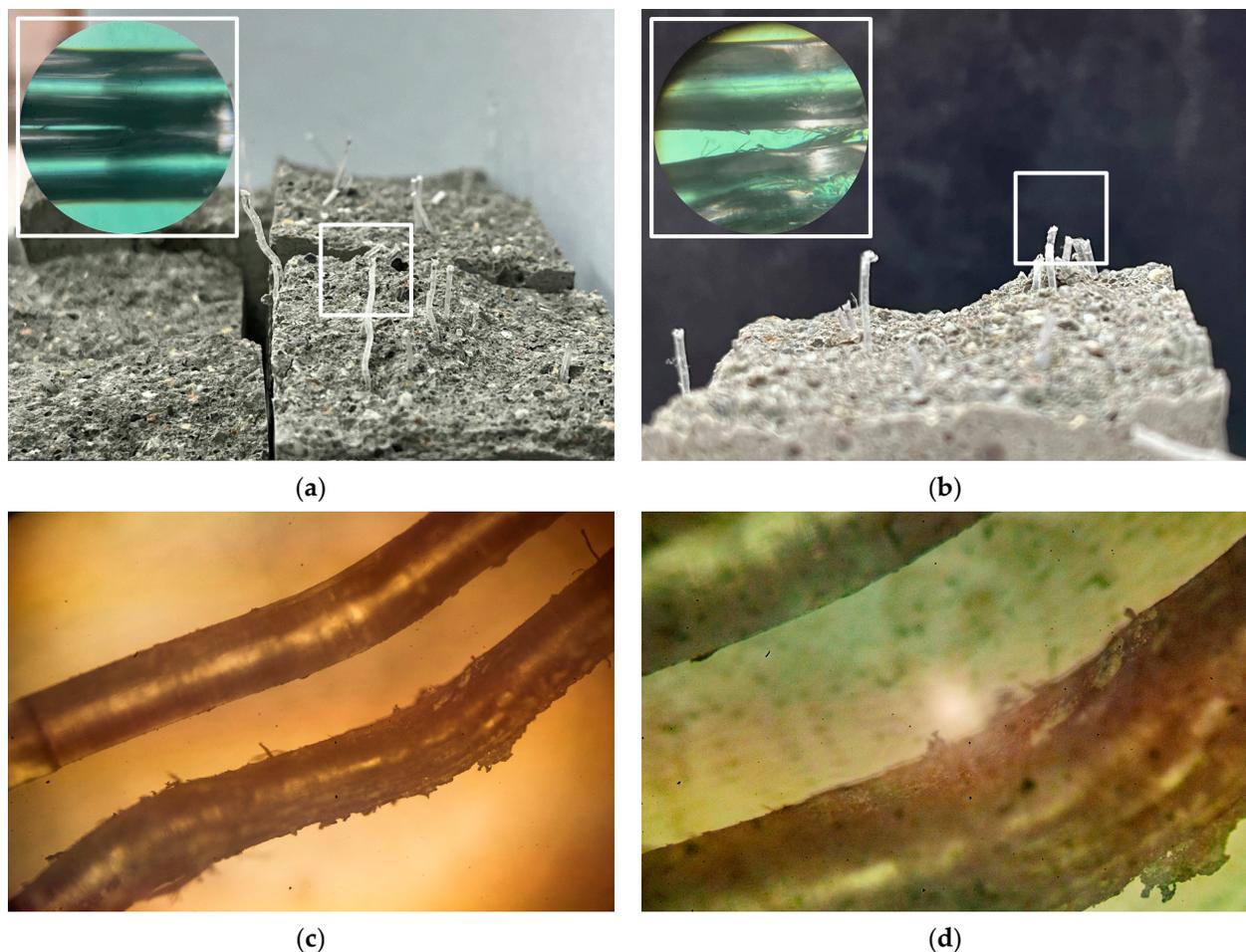


Figure 7. Fractures of PP fiber mortar specimens after flexural strength test and the image of the fibers after their pull-out from the cementitious matrix: (a) mortars with non-modified fibers; (b) mortars with TA-modified fibers (macro-observation and micro-observation under magnification: $50\times$); (c) non-modified (upper) and modified (lower) fibers (magnification: $50.4\times$); (d) non-modified (upper) and modified (lower) fibers (magnification: $120\times$).

4. Conclusions

The presented research is a preliminary phase of work on improving the properties of polymer fibers for concrete available on the Polish market. Only one level of fiber dosing was used, and the modified composite was a standard mortar (the so-called comparative

mortar) with Portland cement (although there is a tendency to reduce consumption of high-emission binders). Nevertheless, the results obtained in the presented research are promising. Firstly, after adding polypropylene fibers to mortars in a significant amount, recommended by the manufacturer as reinforcement for concrete for structural applications, there was no significant deterioration in compressive strength (only 11.5–12.3% reduction). Secondly, the modification with tannic acid did not lead in any case (neither after 7 days nor after 28 days) to a deterioration in compressive strength or flexural strength (even a slight improvement was noted). It significantly improved the flexural modulus of the tested fiber mortars. Thirdly, it was confirmed that the surface modification with tannic acid, which was earlier used in the case of different polymers, positively affected the polypropylene fibers, improving their adhesion and anchoring in the cementitious matrix.

The study aimed to evaluate the possibility of improving the performance of the polypropylene fibers in the cement composite with the method previously employed for the polyethylene fibers. The results show that the surface modification method with tannic acid can effectively improve the bonding between a cementitious matrix and the various polymer fibers.

In the subsequent investigation phase, the authors intend to extend the research to include composites with lower water/cement ratio values and fluidizing admixtures. They also intend to shift the scale of the experiment from mortars to concretes with coarse aggregate and to determine properties such as those assessed with the wedge splitting test (WST), which is considered a good measure of adhesion [26–28]. Moreover, they want to investigate the effectiveness of tannic acid modification on other polymer fibers for concrete available on the Polish market, such as copolymer polyolefin fibers.

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Conflicts of Interest: The authors declare no conflicts of interest.

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