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# Properties of Concrete Reinforced with M12 Monofilament Type Polypropylene Fiber

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**Abstract:** In recent years, especially for military structures in areas where terrorist attack incidents are frequent, studies on the development of explosion and rocket resistant concrete with high impact resistance have increased. One of the most important materials used for this purpose is polypropylene fibers. In the literature, studies with monofilament type PP fiber are limited. In this study, M12 monofilament type PP fiber with a diameter of 32 µ was added to concrete at different ratios, and changes occurring in the mechanical properties of concrete, such as shrinkage, flexural, compressive and impact strength, and microstructures were examined. It was determined that there was a 41% decrease in shrinkage, a reduction in compressive strength, a slight improvement in flexural strength, and up to 318% increase in impact strength as fiber addition increased. In the microstructural examinations, it was observed that fiber addition prevented disintegration by keeping cracked pieces together.

**Keywords**: Polypropylene, fiber reinforced concrete, monofilament type fiber, impact resistance, compressive strength

# M12 Monofilament Tipi Polipropilen Lif Takviyeli Betonların Özellikleri

**Özet:** Son yıllarda özellikle terörist saldırı olaylarının sık olduğu bölgelerdeki askeri yapılar için patlama ve rokete dayanıklı betonun yüksek darbe dayanımına sahip geliştirilmesine yönelik çalışmalar artmıştır. Bu amaçla kullanılan en önemli malzemelerden biri polipropilen liflerdir. Literatürde monofilament tipi PP elyaf ile yapılan çalışmalar sınırlıdır. Bu çalışmada; 32µ çapında M12 monofilament tipi PP lif, farklı oranlarda beton içerisine katılmış ve betonun rötre büzülmesi, eğilme, basınç ve çarpma mukavemeti gibi mekanik özelliklerinde meydana gelen değişimler ve mikroyapılar incelenmiştir. Lif katkısı arttıkça, rötre büzülmesinde %41 oranında azalma, basınç dayanımında düşme, eğilme mukavemetinde az miktarda da olsa iyileşme ve çarpma dayanımın da %318' lik bir artış tespit edilmiştir. Mikroyapı incelemelerinde lif katkısının çatlayan parçaları bir arada tutarak dağılmayı engellediği görülmüştür.

**Anahtar Kelimeler**: Polipropilen, elyaf takviyeli beton, monofilament tipi elyaf, darbe dayanımı, basınç dayanımı

## 1. Introduction

Conventional concretes have poor properties in terms of tensile strength, flexural strength, fatigue strength, abrasion resistance, post-crack load carrying capacity, toughness and fire resistance [1-3]. The properties of concrete vary by the mixing method, type of handling, placement, compaction, curing method and duration, type and amount of materials that make up the concrete, and the

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surface s of contact between the materials used [4-6].

Minerals and fibers have been added to concrete since ancient times for various purposes such as increasing the performance of concrete and making it more resistant to external loads, allowing it to have a longer lifetime and mechanical properties, and reducing microcracks on the concrete surface [1,7-9]. Silica fume, fly ash, blast furnace slag, metakaolin, trass, etc. [1,6,10] as mineral addition, and fibers produced from materials such as steel, glass, basalt, polypropylene (PP), polyamide, polyvinyl alcohol, polyethylene, polyester, carbon, aramid, and natural fibers [1-3,7,11,12] as fiber addition are used in the production of concrete. The use of fibers in concrete production has gradually become widespread for reasons such as absorbing the energy caused by the impact loads, keeping concrete together by functioning as a bridge between cracks, preventing disintegration and sudden breakage, and increasing the ductility of concrete [1,2].

The fact that glass fibers caused problems in terms of durability in alkaline environments increased the use of steel and polymer fibers in concrete [2,7,11]. The fact that the mechanical properties of the concrete reinforced with polymer are affected by the properties of both binding phases, high adhesiveness needed for surface coating concrete to be applied in bridges and slabs, high flexural strength and low permeability values, the fact that it does not create a magnetic field, high corrosion resistance, and allowing to obtain better mechanical properties compared to conventional concrete have led to the increased use of polymer fibers all over the world [2,4,11]. Due to these properties provided by polymer fiber addition, polymer-reinforced concrete is used in reinforcement works [2,3,5,9,12], structures exposed to high temperature [2,7,13], high structures [2,3,14], road constructions [1,2,3,6,15], airport runway pavements [1-3,6], slopes with slope stability problems [2,3,7], railroad ties [1,15], thin-shell structures [2,3,9], concrete pipes [1-3], industrial grounds [2,5,15], explosion and rocket resistant military structures [1,2,5], prestressed structures [2,15], places where magnetic field is undesirable [5,12], bridges [1,2,4], submarine structures where corrosion resistance is desired [2,5,7,11], and nuclear power plants [1,2].

Nowadays, polypropylene fibers are more preferred by concrete companies for reasons such as the good filling of gaps in concrete, decreasing shrinkage cracks, increasing toughness and impact resistance, and improving overall durability properties such as abrasion, defrosting, disintegration, dusting and flaking resistance [2,3,7,13]. In the literature reviews, it appears that more academic studies have been carried out regarding the use of PP fibers in concrete especially in recent years [1,2,3,7]. In some studies carried out in Turkey, how M03, M06, F12, and M19 type PP fibers affected the properties of mortars in the hardened state [2], effects of M13 type PP fibers on freeze-thaw and abrasion resistance of concrete [3], development of materials with M19 type PP fiber alternative to steel fibers with two hooks [5], mechanical and physical properties of M03, F06 and F19 type PP fibers on plaster and concrete samples [7], effect of M18 type PP fiber on the durability of white concrete [9], modeling of fiber reinforced concrete by the finite elements method [11], effect of Polifer 635 commercial code PP fibers on workability in self-compacting concrete [13] were investigated.

PP is one of the most widely used polymers [16]. Sarıkaya and Susurluk [17] investigated the physical and mechanical properties of concretes obtained by using different proportions of polypropylene fibers by keeping the cement amount constant in concrete mixtures. According to to the researchers, the increasing fiber rate in the concrete mixtures, flexural strength and compressive strength was increased by addition of fibers to concrete. In similar studies carried out around the world, the production of M24 type PP fiber reinforced magnesium-phosphate cement composites for quick repair applications [14], dynamic properties of concrete slabs reinforced with M19 type PP fiber by 0.1% and 0.5% [15], comparison of the properties of reinforced concrete which changes depending on PP fiber dimensions [18], effects of the use of PP-Steel fiber on the hardening properties and impact resistance of concrete [19,20], usability of PP fiber with recycled aggregate

[21], effects of PP fibers on the properties of reinforced concrete structures [22-24], effects of inorganic additives and surface modified PP fibers on rheological, thermal, thermomechanical and mechanical properties of concrete [25], effect of PP fibers on the burning property of concrete [26], determination of an ideal PP fiber ratio for improving compressive and flexural strength of concrete [27], statistical analysis of PP fiber reinforced concrete [28], reinforcing of concrete and cement mixtures with M5, M10, M15, M24 type PP fibers [29] were investigated.

In the literature reviews, it was indicated by researchers that the properties of fibrous concrete significantly differed depending on fiber geometry (monofilament or film), fiber content, fiber length and diameter, tensile stress, slenderness ratio, and that impact resistances should be examined for different types of aggregate and fibers [1,3,13,15,29,30]. In the literature, it was determined that the studies carried out with M12-type fibers were limited [18,20,23,26], fibers with a diameter of 18 μ [19,26] and 22 μ [20,23] were mostly studied, and there was no study on the effect of intensely used M12 type PP fiber with a diameter of 32 μ [3,12] on the mechanical properties of concrete. In this study, it was aimed to examine changes occurring in the mechanical properties and micro-structures of concrete by adding M12 monofilament type PP fiber with a diameter of 32 μ and a density of 0.905 g/cm$^3$ to concrete at different ratios, and to determine the ideal microstructures, and to determine the ideal amount of fiber to increase the impact resistance of concrete when M12 type PP fiber with a diameter of 32 μ was used.

## 2. Experimental Methods

### 2.1. Materials and Methods

In the studies, 12 mm long monofilament type (M12) PP fiber was used as a fiber. Monofilament type PP fiber reduces shrinkage cracks occurring especially in the plastic phase of concrete or plaster, and damages caused by burning [2,4,7,8]. The technical properties of the fiber used are presented in Table 1, and the images are presented in Figure 1.

**Table 1.** Technical properties of monofilament type PP fiber

| Description | Value | Unit |
|---|---|---|
| Length | 12 ± 2 | mm |
| Diameter | 32 ± 3 | μ |
| Amount per unit volume | 7.3 ± 1.1 | dtex |
| Elongation (nominal) | 280 | % |
| Elongation (minimum average) | 190 | % |
| Tensile strength (nominal) | 28 | cN/tex |
| Tensile strength (minimum average) | 23 | cN/tex |
| Melting point | 165 | ˚C |
| Density | 0.905 | g/cm$^3$ |

CEM I 42,5 N type Portland cement as a binder, river aggregate, and potable tap water as mixing water were used in the preparation of samples. The amounts of slump of concretes were fixed at 50-90 mm, and the amount of mixing water was determined accordingly. Aggregate of 4 mm maximum size with a density of 2.73 g/cm$^3$ was used for 40x40x40 mm and 40x40x160 mm samples. In the samples with a size of 100x100x100 mm and 100x100x500 mm, the sand part of the aggregate of 4 mm maximum size was added to the mixture and 16 mm maximum coarse aggregate (density 2.67 g/cm$^3$). The chemical and physical properties of CEM I 42,5 N type Portland cement are presented in Table 2.

**Figure 1.** Monofilament type PP fiber

**Table 2.** Chemical and Physical Properties of CEM I 42,5 N type Portland Cement

| Property | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | K.K. | Blaine | Self-weight | $F_{ce}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Value | 21.2 | 5.62 | 3.24 | 62.94 | 2.73 | 1.79 | 1.78 | 3382 | 3.07 | 51.7 |
| Unit | % | % | % | % | % | % | % | $cm^2/g$ | $g/cm^3$ | % |

40x40x40x mm and 100x100x100 mm cube compression test samples according to TS EN 12390-3), 160x40x40 mm and 500x100x100 mm prism flexural test samples (TS EN 12390-5), and 100x100x100 mm cube impact test samples [30] were produced using steel molds in accordance with the parameters and standards given in Table 3. The mixture prepared according to TS EN 196-1 standard using a mixer was placed in steel molds by vibration in three stages, and the samples were compacted by rodding 25 times at every stage. After the mixture was placed in the mold, the top surface was smoothed, and the samples covered with a wet cloth were kept in the mold for one day until they hardened. The samples removed from the mold were kept in lime-saturated water at room temperature for 28 days for the curing process. The compressive strength, flexural tensile strength, and impact energy tests were performed on the devices in Fırat University Construction Department Laboratory (Turkey) to determine the mechanical properties of the samples removed from the cure on the 29th day.

**Table 3.** Parameters used in the study

| Sample code | Sample size (mm) | | | PP fiber ratio (%) |
|---|---|---|---|---|
| | Flexural | Compressive | Impact | |
| Ref-1 | 160x160x40 | 40x40x40 | - | - |
| N-1F02 | 160x160x40 | 40x40x40 | - | 0.2 |
| N-1F04 | 160x160x40 | 40x40x40 | - | 0.4 |
| N-1F06 | 160x160x40 | 40x40x40 | - | 0.6 |
| N-1F08 | 160x160x40 | 40x40x40 | - | 0.8 |
| N-1F10 | 160x160x40 | 40x40x40 | - | 1.0 |
| Ref-2 | 100x100x500 | 100x100x100 | 100x100x100 | - |
| N-2F25 | 100x100x500 | 100x100x100 | 100x100x100 | 0.25 |
| N-2F50 | 100x100x500 | 100x100x100 | 100x100x100 | 0.50 |
| N-2F75 | 100x100x500 | 100x100x100 | 100x100x100 | 0.75 |

## 2.2. Shrinkage Test

Shrinkage measurements were performed in accordance with TS 3453 standard on three prism-shaped samples with a size of 160x160x40 mm by following length reduction rates under 45±5% relative humidity and 22±2 ˚C temperature conditions.

### 2.3. Mechanical Test

Shrinkage measurements were performed in accordance with TS 3453 standard on three prism-shaped samples with a size of 160x160x40 mm by following length reduction rates under 45±5% relative humidity and 22±2 ˚C temperature conditions.

Compressive strength tests were performed with a hydraulic load-controlled press at 3 kN/sec loading speed. Compressive strength was calculated according to equation (1) and by rounding to integer. In the equation, $f_c$ (MPa) refers to compressive strength, F (N) refers to breaking load, $A_c$ ($mm^2$) refers to the average cross-sectional area of the test sample. The flexural tensile test was performed in the hydraulic load-controlled test press, which consisted of the loading head and the loading press and was also used in compression test. In the flexural strength test, equation (2) was used in the calculation of breakage. Equation 2 is valid for third point loading in flexural strength test. in the equation, $f_{cf}$ (MPa) refers to flexural strength, F (N) refers to the maximum load at the moment of breaking, $l$ (mm) refers to the clear span between support bracket, $d_1$ (mm) refers to the average width of the breakage section, and $d_2$ (mm) refers to the average height of the breakage section. For the impact test, a specially designed test device suitable for the purpose was used as indicated in the literature [1,6,30]. In the impact test, samples were placed at the lower part of the test device, and a steel cylinder weighing 13.5 kg was dropped on the samples from a height of 25 cm. It was observed that the method had been previously used in similar studies in the literature [1,2,6,30]. Equation (3) was used in the calculation of impact energy [1]. In the equation, $E_1$ (Nm) refers to impact energy, M (kg) refers to the weight of the cylinder, $V_1$ (m/s) refers to impact speed, and N refers to the number of impacts until the samples were slumped.

$$f_c = F / A_c \quad (1)$$

$$f_{cf} = (F/l) / (d_1.d_2^2) \quad (2)$$

$$E_1 = MV_1^2N / 2 \quad (3)$$

### 2.4. Microstructural Examinations

The morphological properties of the samples, adherence between polypropylene fibers and mortar were examined with an FEI Srion brand SEM device in the Metallurgical and Materials Engineering Laboratory of Marmara University. The samples were coated with 100 A gold under vacuum to obtain an inert and permeable surface, and the microstructures were photographed under 20 Kv voltage.

## 3. Results and Discussion

### 3.1. Shrinkage Test

The measurement results of the shrinkage test performed by following the shrinkage ratio are presented in Table 4.

**Table 4.** Shrinkage determination test results

| Sample code | PP fiber ratio (%) | Change in length (%) | Performance (%) |
|---|---|---|---|
| Ref-1 | - | 0.1872 | - |
| N-1F02 | 0.2 | 0.1685 | +11 |
| N-1F04 | 0.4 | 0.1603 | +17 |
| N-1F06 | 0.6 | 0.1513 | +24 |
| N-1F08 | 0.8 | 0.1405 | +33 |
| N-1F10 | 1.0 | 0.1325 | +41 |

The drying shrinkage values of concretes without reinforcement and reinforced with PP fiber were measured differently from each other. Shrinkage decreased by up to 41% as the fiber ratio increased. In the studies carried out it was indicated that the use of PP fiber decreased shrinkage cracks and shrinkage [2,4,7]. It was considered to be due to the fiber bridges provided between the aggregate and cement paste. It was determined that internal stresses due to shrinkage decreased as the fiber ratio increased, which decreased and even usually removed the shrinkage cracks.

### 3.2. Mechanical Tests

The compression and flexural test results calculated according to equation (1) and equation (2) are presented in Table 5, and their graphical comparison is presented in Figure 2 and Figure 3. When the compressive strength results were examined, it was observed that fiber reinforced concrete exhibited less performance than concrete without fiber addition and that the compressive strength decreased as the amount of fiber reinforcement increased, which is thought to be caused by the difference in density in the structure. It was due to the fact that the density of fiber was lower than the density of concrete. In similar studies in the literature, it was reported by researchers that the compressive strength results of PP fiber reinforced concrete were obtained in a similar way and that the low strength of the fibers in compression decreased the compressive strength of the concrete [2,4,5]. Widodo et al. used steel fiber along with PP fiber to increase compressive strength and achieved better results in compressive strength by balancing the density difference [19].

**Table 5.** Compressive and flexural strength test results

| Sample code | PP fiber (%) | Compressive Strength | | Flexural Strength | |
|---|---|---|---|---|---|
| | | Value (MPa) | Performance (%) | Value (MPa) | Performance (%) |
| Ref-1 | - | 64.80 | 0 | 8.45 | 0 |
| N-1F02 | 0.2 | 64.50 | -0.46 | 8.75 | +3.55 |
| N-1F04 | 0.4 | 57.60 | -11.11 | 8.90 | +5.33 |
| N-1F06 | 0.6 | 54.40 | -16.05 | 8.40 | -0.59 |
| N-1F08 | 0.8 | 54.30 | -16.20 | 8.55 | +1.18 |
| N-1F10 | 1.0 | 53.10 | -18.06 | 8.35 | -1.18 |
| Ref-2 | - | 59.30 | 0 | 1.902 | 0 |
| N-2F25 | 0.25 | 58.81 | -0.83 | 1.952 | +2.63 |
| N-2F50 | 0.50 | 55.24 | -6.85 | 1.978 | +4.0 |
| N-2F75 | 0.75 | 53.06 | -10.52 | 2.0925 | +10.02 |

When flexural test results were examined, it was found that there was a more negligible improvement in the flexural strength of fiber reinforced concrete compared to concrete without fiber addition. It was observed that there was a decrease in the flexural strength of samples with a PP fiber addition ratio of 0.6% and 1%. It is considered to be due to factors such as the sensitivity of the concrete production process, and the gaps in concrete caused by poor concrete compaction. This will be better understood by microstructural examinations of samples with reduced flexural strength. In the study carried out by Topçu et al. with different types of PP fibers, it was stated that the flexural strength was directly associated with the amount of fiber added to the concrete and the fiber type, and the flexural strength increased along with the increase in the amount of fiber in the concrete [3]. In the study carried out by Ünal et al., it was reported that brittle fractures were observed in concrete with and without fiber addition [2]. In the study carried out by İpek et al., it was observed that most of the fibers were broken after a certain deflection depending on the amount of flexure [6]. Erbaş indicated that fiber addition increased flexural strength by preventing the disintegration of concrete just after the breaking load [7].

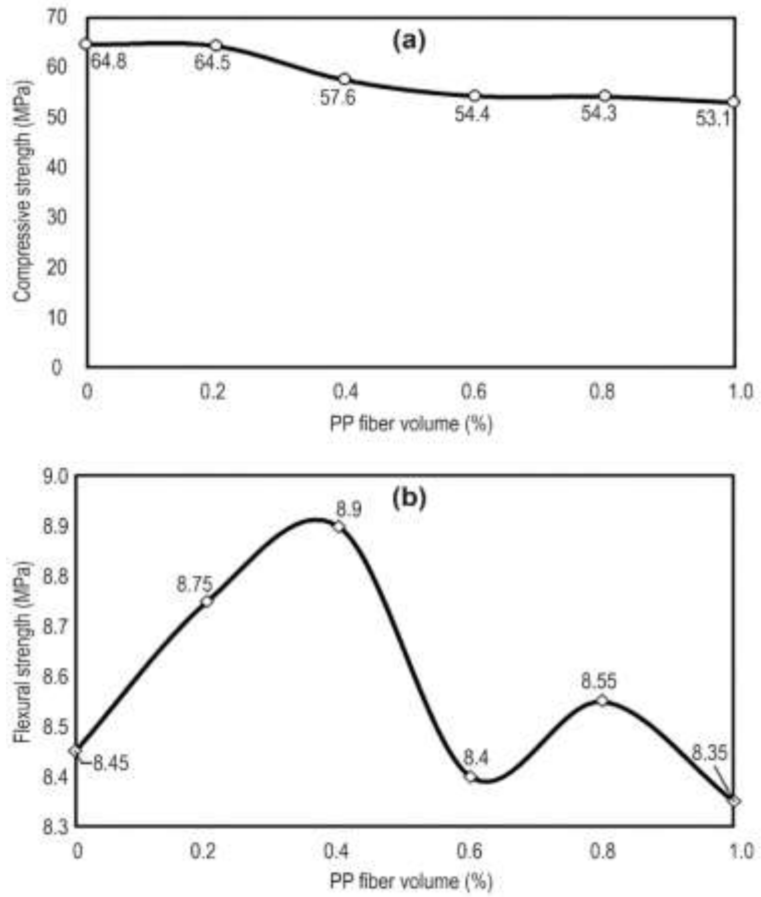


**Figure 2.** Graphical comparison of (a) compressive and (b) flexural strength with sample size 40x40x40

The speed ($V_1$) of the steel cylinder at the moment of impact was measured to be 1.25 m/s. The impact energy calculated according to equation (3) and the number of impacts are presented in Table 6. The effect of fiber ratio on the impact energy of concrete is presented in Figure 4. The highest impact performance was obtained in the sample with a PP fiber ratio of 0.75. It was observed that the number of impacts and consequently the impact energy increased as the fiber content in concrete increased. The addition of PP fiber improved the impact energy of concrete at satisfactory levels. It is thought to be due to the fact that PP fiber absorbed the load on concrete, limited the formation of cracks and prevented disintegration by acting as a bridge between cracks. In similar studies carried out by the researchers, it was determined that PP fiber addition increased the impact strength of concrete and that similar results were obtained [1,3,5,7]. In concretes in which PP fiber is used, the building will be less affected by environmental conditions and will last longer compared to concrete without PP fiber addition [7,8]. It was stated by Yazıcıoğlu et al. and Oltulu & Altun that impact strength should be high in places such as water structures, railroad ties, especially military buildings exposed to the explosive effect, nuclear power, and industrial buildings [1,4]. Manolis et al. indicated that the amount of fiber used was related to impact performance and that impact resistance increased as the amount of PP fiber increased [15]. Nia et al. explained obtaining higher impact resistance when PP fiber was used by the fact that PP fibers form better bonds with concrete [20]. In concrete mixes prepared by Akça et al. using recycled aggregate, it was observed that the use of PP fiber increased impact resistance [21].

### 3.3. Microstructural Examinations

SEM images of Ref-1 coded samples with x35 and x150 magnification are presented in Figure 5a, and SEM images of Ref-2 coded samples with x35 and x1000 magnification are presented in Figure

5b. When the SEM images of control samples were examined, it was observed that the mixture was homogeneous and that the curing process was performed successfully, which is a consequence of correct mechanical mixing at the beginning.

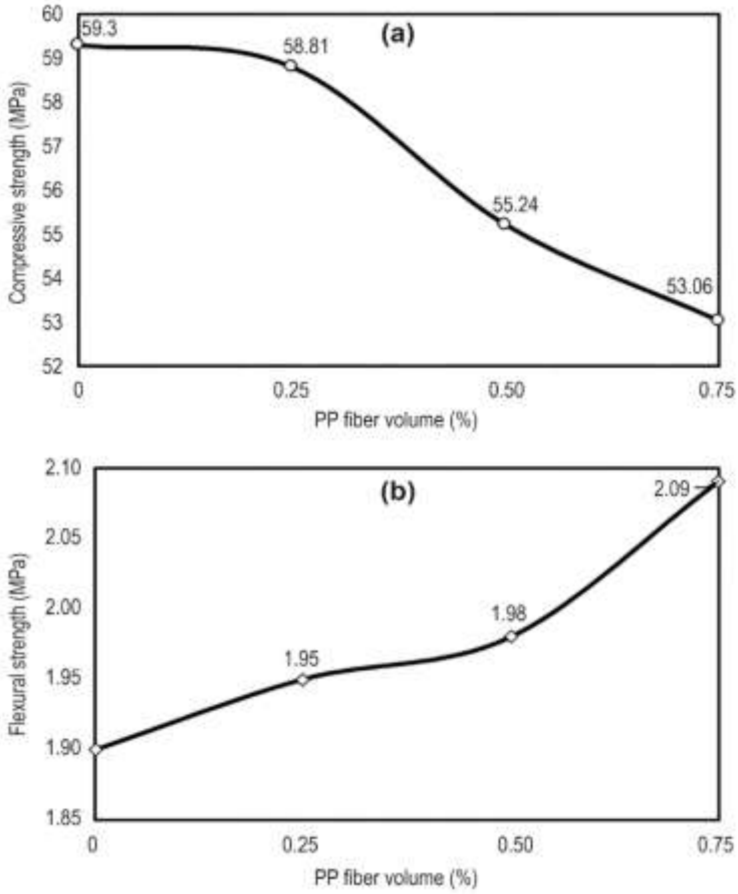


**Figure 3.** Graphical comparison of (a) compressive and (b) flexural strength with sample size 100x100x100

In the microstructural examinations of control samples, highly concentrated cement hydration products were observed around the aggregate. This strong adherence between the aggregate and cement was considered to be effective in high compressive strength. In the study of Topçu et al., similar microstructures were also found in concrete without fiber addition [3]. When breakage surfaces were examined, it was determined that the broken piece was completely away from the structure, cracks developed uncontrollably, and cracked pieces would be away from the structure by breaking in a small vibration/shock.

In fiber-reinforced concrete samples, it was observed that the fiber was homogeneously distributed in the structure and prevented the disintegration of the structure by keeping cracked pieces together. Although this situation does not seem very clear in Figure 6a depending on the fiber ratio, it is more clearly observed in the SEM images of samples with a high fiber ratio as in Figure 6c. As it is seen in Figure 6a, Figure 6b, Figure 6e, Figure 7a, and Figure 7b, it was determined that fiber was generally distributed homogeneously to the structure in fiber reinforced concrete. Erbaş indicated that M12 type fibers could be distributed homogeneously more easily in concrete mixtures [7]. Ünal et al. stated that the homogeneous distribution of fibers added to concrete in the mixture and then the preservation of this situation directly affected the improvement to be made by fibers on the properties of concrete [2].

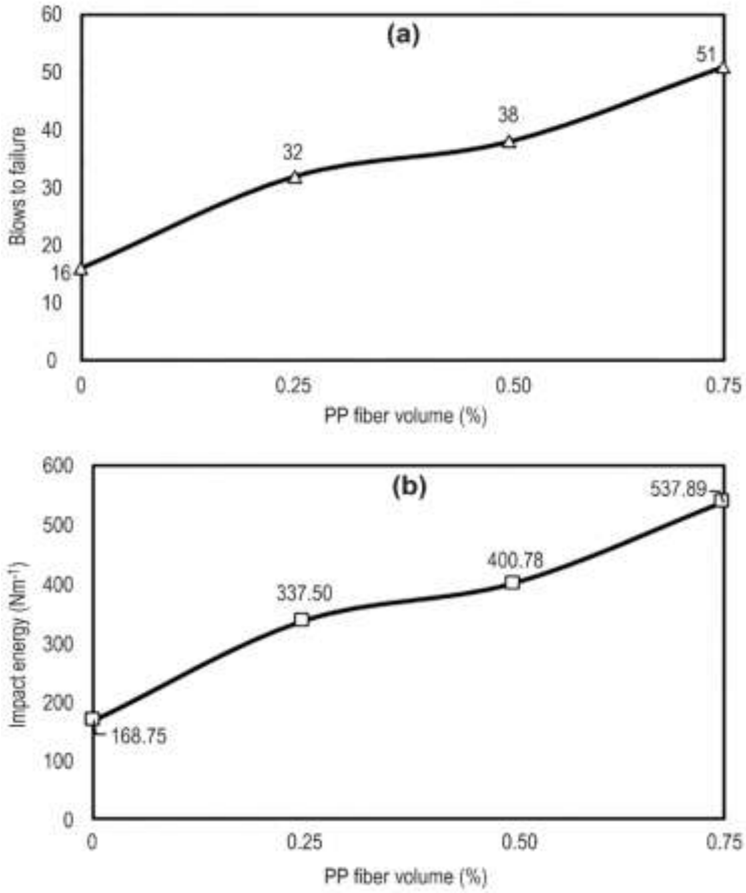


**Figure 4.** Effect of fiber ratio on impact properties

In the observation made on fiber-reinforced concrete, it was observed that adherence was not good enough although dense cement hydration products were found around PP fiber. It was due to the PP fiber surface. It is estimated that the relative decrease in compressive strength compared to the control sample was due to it. In the study of Horbanová et al., it was stated that surface-modified PP fibers with inorganic additives improved the rheological, thermal, thermomechanical, and mechanical properties of concrete [25].

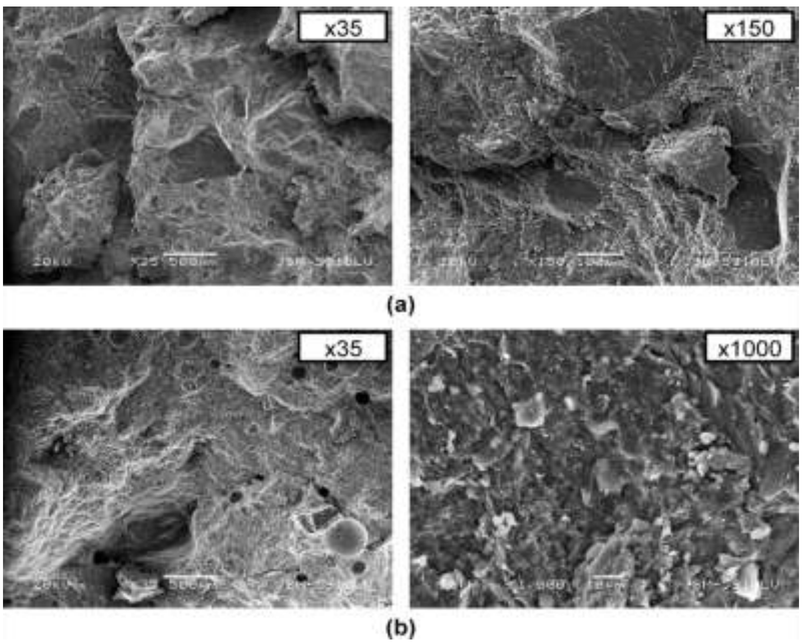


**Figure 5.** SEM images of control samples, (a) Ref-1, (b) Ref-2

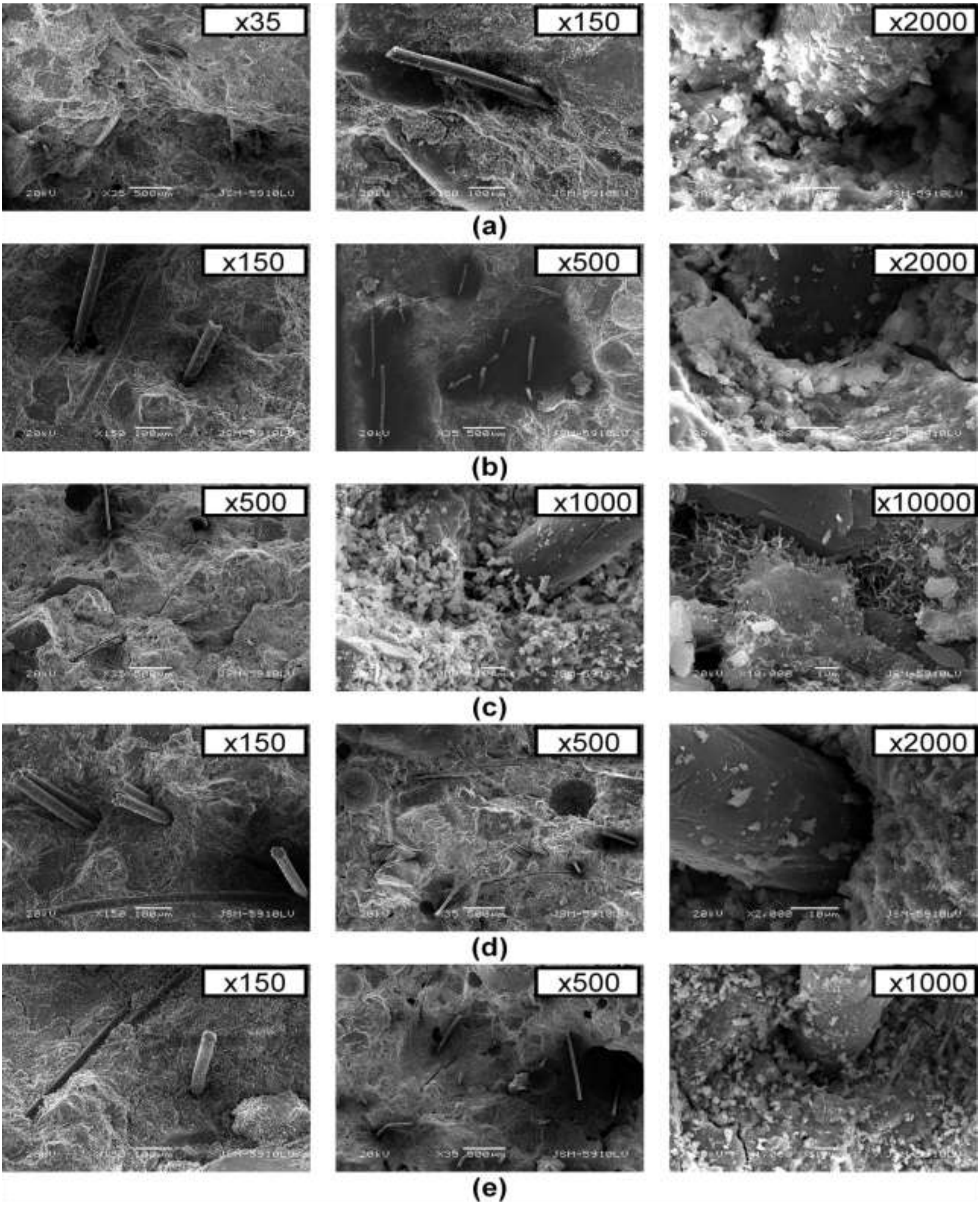


**Figure 6.** SEM images of concrete composite reinforced, (a) 0.2 % PP fiber, (b) 0.4 % PP fiber, (c) 0.6 % PP fiber, (d) 0.8 % PP fiber, (e) 1.0 % PP fiber

In fiber reinforced concrete, the surface treatment of PP fibers will enable obtaining higher compressive strength. In flexural strength, the fact that a relatively better flexural strength was obtained from fiber-reinforced concrete compared to the control sample indicated that adherence between PP fibers and cement hydration was not too weak. Increased flexural strength along with an increased fiber volume confirms it. The results obtained from the study carried out by Topçu et al. [3] were also similar to the results in this study.

In the samples in Figure 6c, Figure 6d, and Figure 7c, agglomeration was found in PP fiber, although it was very slight. Here, agglomeration refers to the difference in the ratio of fiber per area rather than flocculent fiber, or the presence of two fibers side by side in the concrete. When SEM images were examined, it was observed that fibers had integrity with concrete and limited breakage/crack propagation in all samples. Even in visual inspections, it was possible to see that fibers did not leave broken pieces on broken surfaces. Kakooei et al. stated that it was due to the characteristic properties of PP fibers [24]. Broken/cracked pieces do not remain on the sample surface in control samples without addition. It is considered that this situation will minimize the damage that may occur in various damages that may occur in fiber reinforced concrete structures during the life cycle and will slow down the damage formation rate, which will allow detection of any damage to the structure without breaking or demolishing.

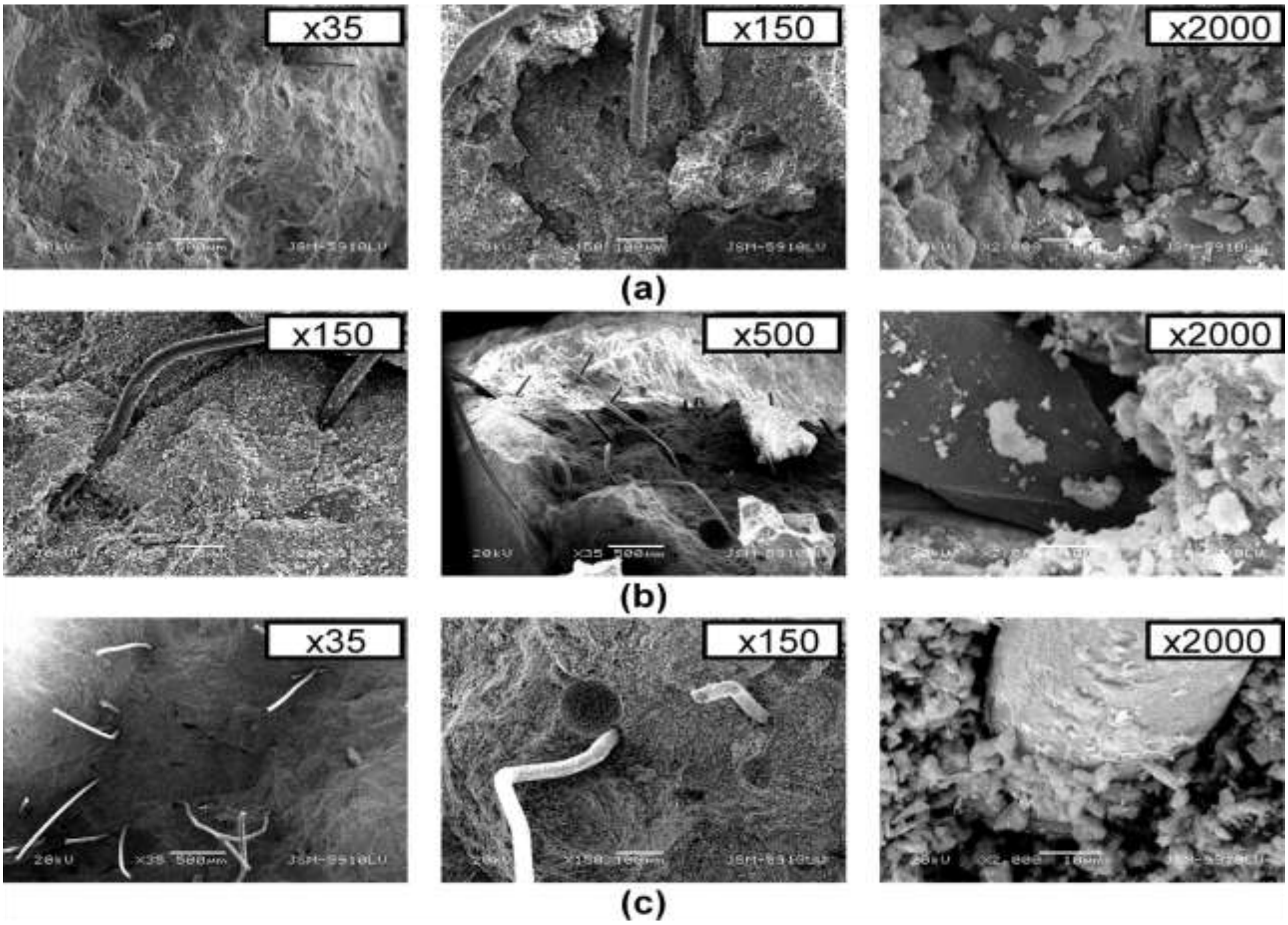


**Figure 7.** SEM images of concrete composite reinforced, (a) 0.25 % PP fiber, (b) 0.50 % PP fiber, (c) 0.75 % PP fiber

## 4. Conclusions

In this study, the mechanical properties of concrete reinforced with M12 monofilament type PP fiber with a diameter of 32 μ, and microstructures were examined experimentally. The main results obtained from this study can be explained as follows:

1. PP fibers are synthetic fibers that are commonly used in concrete production due to their density and economy. Continuous monofilament fibers can be used in concrete for different purposes by cutting at desired dimensions or in the form of film.

2. Fiber addition decreased shrinkage cracks, which are effective in the first hours after pouring mortar in concrete and affect the lifetime of the structure, which led to a significant advantage compared to concrete without fiber addition.
3. The additive from the mixture may not be sufficient for homogeneity under mass production conditions. In concrete mixtures in which fiber addition will be used, the activities to improve the mixture should be applied to ensure a homogeneous distribution throughout the concrete. Therefore, distribution/mixture performances of fibers of different sizes in concrete should be examined.
4. PP fiber addition had a reducing effect on the compressive strength of the materials depending on the concrete and fiber density.
5. PP fiber addition has a slightly improving effect on the flexural strength of materials when attention is paid to production conditions.
6. It will be effective to improve concrete and fiber interfaces or to apply surface treatment to the fiber in order to obtain maximum performance from compressive and flexural strength of fiber reinforced concrete.
7. PP fiber addition improves the impact energy and the number of impacts of materials at satisfactory levels. Concrete composite structures with PP fiber will last longer since they will be less affected by environmental conditions compared to structures without fiber.
8. The use of PP fiber slows down the formation rate of damages that may occur in the structure. It will be guiding in taking precautions or reducing/preventing loss of life since it can be observed before the structure is broken or destroyed.

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