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Evaluating the effect of sample size on the flexural strength of concrete containing polyethylene terephthalate fibers with the optimal content

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Abstract

This study investigates the impact of specimen size on the flexural strength of concrete reinforced with optimized polyethylene terephthalate (PET) fibers. A series of experimental tests were conducted using various PET fiber ratios (0.5 to 1.5% by the total volume of the mix) and lengths (15, 30, and 45 mm) to highlight the optimized PET fiber in concrete. Flexural strength tests were carried out on prismatic specimens of varying sizes (100x100x400 mm, 100x150x500 mm, and 100x200x700 mm) and different concrete grades (20, 35, and 45 MPa). The findings indicate a significant improvement in the splitting tensile strength of the concrete, reaching up to 18.43% with the addition of PET fibers. These fibers effectively act as bridges across cracks, reducing their width and halting their propagation. The optimal PET fiber length was identified as 30 mm, added to the concrete at a rate of 1% by the total volume of the mix. Moreover, the results revealed a noticeable effect of the specimen size on the flexural strength of PET fiber-reinforced concrete, with an inverse relationship between specimen size and measured flexural strength. As the size of the specimen increased, the flexural strength decreased. Based on the experimental data, an empirical relationship was developed to quantify the flexural strength of optimized PET fiber-reinforced concrete considering the size effect. These relationships provide practical tools for engineers to accurately account for the size effect in the design and analysis of fiber-reinforced concrete structures.

Keywords: PET fiber, compressive strength, splitting tensile strength, flexural strength, size effect, regression analysis.

1. Introduction

Concrete is widely used in the construction sector due to its excellent compressive strength. However, its inherent brittleness and limited tensile strength make it prones to cracking and failure when subjected to bending or tensile stresses. To address these limitations, fiber reinforcement has been extensively studied and applied to enhance the flexural performance of concrete [1, 2]. In this regard, plastic waste has become a significant environmental concern, but innovative solutions are emerging to tackle this issue. One promising application is the utilization of plastic waste as a fiber in concrete production. The use of plastic waste in concrete not only helps in waste reduction but also contributes to the development of sustainable and eco-friendly construction practices [3]. Furthermore, the use of fibers as a reinforcement material in concrete has gained increasing attention in recent years. Various types of fibers, including steel, synthetic, and natural fibers, have been used to improve the mechanical and durability properties of concrete [1, 4]. Among the synthetic fibers, polyethylene terephthalate (PET) fibers exhibit excellent tensile strength, corrosion resistance, and ease of handling and mixing with concrete [5]. These characteristics make them an attractive choice for improving the flexural behavior of concrete structures.

Numerous studies have explored the impact of PET fibers on the mechanical performance of concrete beams. Kim et al. [6] found that the addition of PET fibers with a volume fraction of 1.0% enhanced the flexural strength of concrete beams up to 30%. The researchers noted that the PET fibers effectively bridged the cracks, enhancing ductility and reducing drying shrinkage. Similarly, Al-Hadithi et al. [7] reported that the inclusion of PET fibers improved the load-carrying capacity and ductility of concrete beams. They attributed the enhancements to the superior crack resistance imparted by the fibers. Furthermore, in the laboratory experiments conducted by Nibudey et al. [8], the use of 1% PET fiber with an aspect ratio of 35 led to enhancements in the compressive, splitting, and flexural strengths by 5.26%, 15.47%, and 17.32%, respectively. Similarly, for fibers with an aspect ratio of 50, the improvements were 7.35%, 24.91%, and 24.105% in the compressive, splitting tensile, and flexural strengths, respectively. Consequently, employing fibers with higher aspect ratios proves beneficial in enhancing strength. The authors also noticed that the mechanical properties reduced with the increase in the fiber volumes.

While the influence of fiber reinforcement on the mechanical properties of concrete has been widely investigated, the effect of specimen size on the flexural strength of fiber-reinforced concrete remains an important research area. The size effect refers to the phenomenon where the measured mechanical properties of concrete, such as flexural strength, are influenced by the size of the specimen tested [9]. Understanding the size effect is crucial for accurately predicting the behavior of large-scale concrete structures and optimizing their design. It helps engineers account for the potential differences in performance between small-scale laboratory specimens and real-world applications. Experimental studies have shown that as the size of the specimen increases, the modulus of rupture tends to decrease [9-12]. Several factors, including stress redistribution, size-dependent crack propagation, and statistical variations in material strength, have been identified by researchers as contributing to the size effect. Nguyen et al. [10] found that the flexural strength, normalized deflection, and normalized energy absorption capacity of ultra-high-performance hybrid FRC increased significantly[3] as the specimen size decreased, and noticed that the average crack spacing on the bottom surface of the specimen reduced. Furthermore, three different-sized fiber-reinforced cementitious composites (FRCCs) were tested by Kim et al. [11]. They discovered that there was a significant size effect on the flexural behavior of FRCC, with both the flexural strength and deflection capacity increasing as the size of the specimens decreased.

This study aims to evaluate the size effect on the flexural strength of PET fiber-reinforced concrete (PFRC) by performing a series of experimental investigations. The research will involve the preparation of various concrete specimens with different dimensions, adding an optimal amount of PET fibers. The experimental results will be analyzed to evaluate the impact of specimen size on the flexural strength of PFRC. Regression analysis will be employed to identify correlations between specimen size and flexural performance. Furthermore, the outcomes of this research will contribute to advancing our understanding of the size effect on PFRC, providing valuable insights for engineers and designers. The addition of PET waste fiber to concrete is appreciably leading to improved structural performance, durability, and sustainability in the construction industry since it is produced from post-consuming plastic waste bottles.

2. Materials and methods

2.1. Materials

In this study, ordinary Portland cement (Type I ASTM), which was produced by Tasluja Cement Factory/ Sulaymaniyah-Iraq, was used in the concrete mixes. The physical properties of the cement are shown in Table 1, which conforms to ASTM C150 [13].

Table 1. Physical properties of cement

Physical properties	Test results	ASTM C150 specification limits
Setting time (min)		
1) Initial setting time	149	≥ 45 min.
2) Final setting time	187	≤ 600 min
Compressive strength (MPa)		
1) 3 days compressive strength	22.5	≥ 12
2) 7 days compressive strength	27.8	≥ 19

Naturally occurring clean river sand was obtained from a local quarry and used as a fine aggregate (FA), with a dry compacted bulk density of 1750.2 kg/m^3, fineness modulus of 2.55, water absorption of 1.63%, and a saturated surface dry (SSD) specific gravity of 2.69. The particle size distribution was specified according to ASTM C-33 [14] and the results of grading are shown in Fig. 1. Crushed gravel with a nominal maximum size of 12.5 mm, of compacted bulk density of 1578.1 kg/m^3, and a saturated surface dry (SSD) specific gravity of 2.68 was obtained from local rivers. The coarse aggregate was tested for grading following the ASTM (C-33) recommendation and the results are shown in Fig. 1. Drinking water was used for the mixing process and curing specimens. Three different types of PET fiber with different lengths,15, 30, and 45 mm were used in mixes. The average width of the PET fiber was 1.1 mm, the thickness was 0.4 mm and the specific gravity was 1.28.

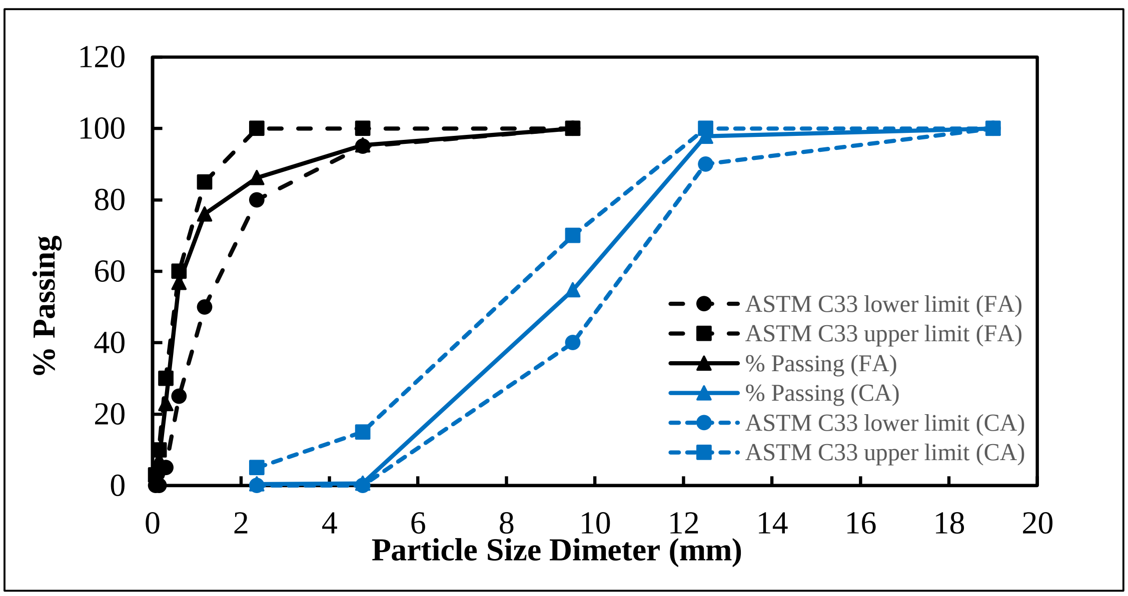


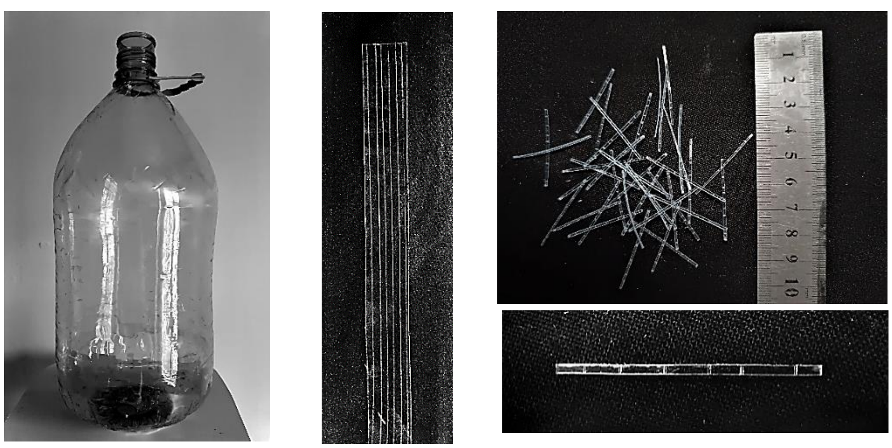
Figure 1. Particle size distribution of fine and coarse aggregates

2.2. Methodology

The experimental program involved casting and testing various concrete mixes to investigate the influence of PET fiber ratio and aspect ratio on the concrete for the compressive and splitting tensile strengths. Optimization for the length and volume fraction of PET fiber was performed based on the results of compressive and splitting tensile strengths before fabricating tested beams. Subsequently, the flexural strength test was performed on beams to investigate the size effect on flexural behavior.

2.2.1 PET Fiber Production

In this study, the PET fiber was prepared by manually cutting 16 litter-capacity post-consumed drinking water bottles as illustrated in Fig.2(a). Initially, the bottom and neck of the bottle were separated and removed due to their thick and irregular cross-sections. Subsequently, the remained portion was longitudinally cut to obtain crenelated recycled PET strips with 15, 30, and 45mm width and 300 mm length (Fig.2(b)). The longitudinal strips were marked with three indents on each side using a cutter knife with a blade thickness of 0.3 mm to increase friction with the concrete matrix. A cutter machine operating at a speed of 0.5 meters per minute (Fig.3) was used to transversally cut the longitudinal strips to the smaller fiber of an average 1.1 mm width (Fig.2(c)).



(a) (b) (c)

Figure 2. Recycling procedure of PET waste water bottles, (a) post-consumer bottles, (b) Longitudinal strip, (c) PET fiber.

Figure 3. Fiber cutting machine

2.2.2 Mix proportion

This research consists of two experimental parts, the first one is finding the optimum volume fraction and length of PET fiber in concrete and for this purpose, the recommendation which was given by ACI 211.1 [15] was monitored to design the concrete mixes with 35 MPa of compressive strength. Results of the mix design showed that the water-to-cement ratio (w/c) is 0.55, cement content is 380 kg/m^3, fine aggregate is 715 Kg/m^3, and coarse aggregate is 1030 Kg/m^3. In addition to the control concrete mixes, a total of twelve mixes were prepared by adding 0.5, 0.75, 1, and 1.5% of PET fiber (by the total volume) having different lengths of 15, 30, and 45 mm.

The second experimental part of the study aimed to evaluate the flexural strength of various prism sizes for concrete mixes with compressive strengths of 20 MPa (M20), 35 MPa (M35), and 45 MPa (M45). These mixes were reinforced with the optimum PET fiber in concrete obtained during the first part experimental work. The mixed proportion of the second experimental part is shown in Table 2.

For mixing concrete, fine and coarse aggregates were equipped at the SSD state before blending, PET fiber with their different length was used all in dry formal. Fine and coarse aggregates were mixed homogeneously in a mixer for 30 seconds. Then about half of the mixing water was added while mixing and continued for another minute. Later, cement was added to the mixture and mixed for another minute. The remaining water was added to the mixer, and the entire contents were mixed for three more minutes. For concrete mixes with PET fiber, after the mentioned steps had been finished the plastic fiber was sprayed evenly onto the concrete. The concrete was then poured into molds. The test specimens were stored in the laboratory for 24 hours. Later, the specimens were de-molded and left in a water tank for 28 days to obtain a well-balanced curried state for the specimens as shown in Fig. 4.

Table 2. Mix proportion of different concrete grades

Material	M45	M35	M20
Cement (kg/m^3)	445.5	376.2	300.0
Water (kg/m^3)	201.0	206.9	209.9
Fine aggregate (kg/m^3)	694.0	707.9	704.9
Coarse aggregate (kg/m^3)	980.1	1019.7	1079.1
w/c	0.45	0.55	0.70
1% PET (kg/m^3)	12.8	12.8	12.8

Figure 4. Curing concrete specimens in water after de-molding

2.2.3 Compressive Strength Test

Three 100x200 mm cylindrical specimens for each mix were cast to evaluate the compressive strength. The specimens were cured, capped with sulfur (Fig. 5(a)) according to ASTM C617M requirements [16], and then tested according to ASTM C39 specification [17], under a loading rate of 0.25 MPa/sec to measure the compressive strength as shown in Fig. 5(b).

2.2.4 Splitting tensile strength test

A 100x200 mm cylinder mold was used to cast three samples in each mix for the splitting tensile strength test, the specimens were cured and then tested according to ASTM C496 [18] under a loading rate of 0.1 MPa/s as shown in Fig. 5(c).

2.2.5 Modulus of rupture test

Three different beams in sizes of (100x100x400, 100x150x500, and 100x200x700) mm were cast for different concrete grades of M20, M35, and M45, the specimens were cured and tested according to ASTM C78 [19] as shown in Fig. 5(d).

(a) (b) (c) (d)

Figure 5. (a) Capping with sulfur, (b) Compressive test, (c) Splitting tensile test, (d) Modulus of rupture test.

3. Results and discussion

3.1. Compressive Strength

The results of the compressive strength of concrete mixes are presented in Fig. 6, which indicates the values of the compressive strength of concrete with reused PET fiber and control concrete. The percentile of compressive strength of concrete containing PET fiber ranges from 83% to 99.5% of control concrete. It can be seen that the addition of a 15 mm length with 0.50% volume content of PET fibers results in reducing the compressive strength of concrete by 1.71%. A further decrease in compressive strength is observed as the length and volume fraction of PET fibers increase as shown in Fig. 6. Concrete containing 1.5% PET fibers of 45 mm length experienced the largest compressive strength reduction of 16.93%. This investigation indicates the significance of considering both the length and volume fraction of PET fibers in concrete mixes, higher amounts of longer fibers tend to have a more pronounced impact on compressive strength.

This study's compressive strength drop corroborates the findings of Borg et al. [4]. They demonstrated that the incorporation of recycled PET fibers had no significant effect on the compressive strength of concrete as they observed compressive strength drops ranging from 0.5 to 8.5% for two fibers (deformed and straight). Consequently, the addition of PET fibers to concrete does not enhance its compressive strength, which is corroborated by studies of Mohammed and Rahim [1], Mohammed and Mohammed [2], Ochi et al. [5], Marthong and Marthong [20], Kim et al. [6], Shahidan et al. [21], Khalid et al. [22] and Ali et al. [23].

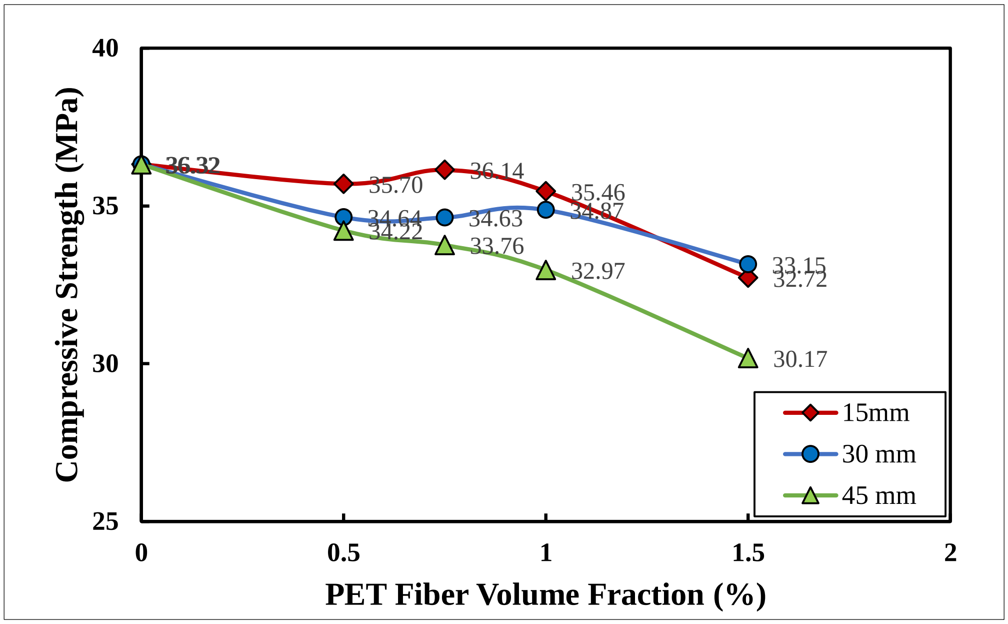


Figure 6. Variation of compressive strength with fiber ratio.

The observed reduction in strength can be attributed to several factors, primarily the formation of fiber agglomerations within the concrete matrix. At higher fiber volume contents, the addition of fibers can lead to the undesired effect of bundling during the mixing and pouring stages, commonly referred to as fiber balling. This occurrence can result in localized concentrations of fibers, creating clusters or clumps that are unevenly distributed throughout the concrete. The non-uniform distribution of fibers can compromise the integrity of the concrete structure, contributing to a decrease in compressive strength [2].

In addition to fiber balling, another significant factor influencing the reduction in strength is incompatibility between the plastic fibers and the concrete matrix. Plastic fibers may not form as effective a bond with the cementitious matrix compared to other types of reinforcing materials. This weakening of the bond can be attributed to the inherent properties of plastic fibers and their interaction with the cement paste. The weaker bond between plastic fibers and the concrete matrix limits their ability to efficiently distribute and transfer stresses within the material. Effective stress distribution is critical for maintaining compressive strength, and when this is compromised due to poor bonding, the overall strength of the concrete structure is adversely affected. [2, 23-25].

3.2. Splitting Tensile Strength

Fig.7 illustrates the variation of splitting tensile strength of concrete with volume fractions of different fiber lengths. According to the results, the splitting tensile strength reached the peack with the addition of PET fibers up to 1% for fiber lengths of 30 mm and exhibited the highest tensile strength improvement of 18.43%. Subsequently, when more fibers were added up to 1.5% for 15 mm and 30 mm, the tensile strength increased by 1.51% and 10.57% respectively, Conversely, the addition of 1.5% of 45 mm fibers led to a reduction in tensile strength by 0.91%. In general, all mixes perform better in terms of tensile strength when compared to compressive strength. The outcomes indicated that the percentage of tensile strength of concrete containing PET fiber ranged from 99.09% to 118.43% of the control concrete's strength. Furthermore, it is observed that the maximum splitting tensile strength of PET fiber lengths of 15 mm and 45 mm is 8.46% and 12.69% for volume fractions of 1% and 0.75% respectively. This implies that different fiber lengths have varying impacts on tensile strength, with the 30 mm length demonstrating the highest performance, as indicated in Fig. 8.

Experimental data by Nibudey et al. [8] on normal concrete showed that utilizing 1% PET fiber with aspect ratios of 35 and 50 resulted in maximum splitting tensile improvements of 15.47% and 24.91%, respectively. Furthermore, in the study by Irwan et al. [26], PET fiber can improve the splitting tensile strength of concrete cylinders containing 0.5% to 1.5% PET fiber. They found that the improvement of splitting tensile strength of concrete containing PET fiber at 0.5%, 1.0%, and 1.5% reached 9.1%, 15.5%, and 23.6%, respectively. Ali et al. [23] found that at 0.5% and 1% PET fiber percentages, conventional concrete improved by 12.5% and 5.3%, respectively. They identified that the PET fibers limit the formation of tensile cracks and their expansion, as previously published.

The enhancement in tensile strength was proportional to the ratio of PET fiber used. The effect of PET fibers has a greater impact on tensile strength improvement compared to compressive strength. This behavior has been observed in previous studies and recommended for applications in normal-strength concrete rather than high-strength concrete [1, 26]. The bridging mechanism of recycled PET fibers enhanced the splitting tensile strength, and beyond convinced ratios, it minimized the bonding strength between concrete components [21]. Figure 9 shows a synthetic fiber bridging in a concrete matrix. As the concrete reaches its tensile strength limit, the stress is transferred to the PET fibers and the frictional forces between the fiber surface and the concrete matrix provide some resistance. Additionally, fibers can prevent the propagation of macro cracks, and delay the concrete's ultimate failure, and consequently, it results in an enhancement of splitting tensile strength [27].

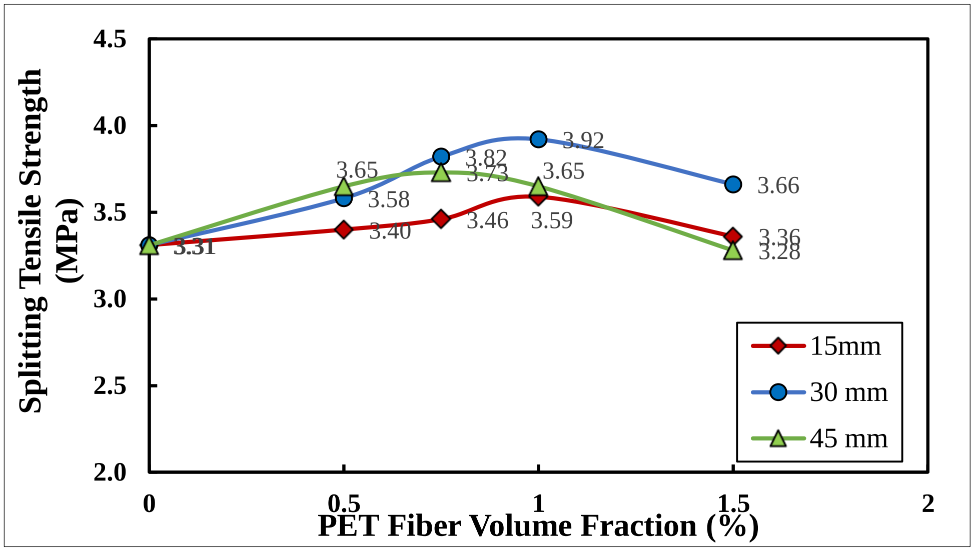


Figure 7. Variation of splitting tensile strength with fiber content

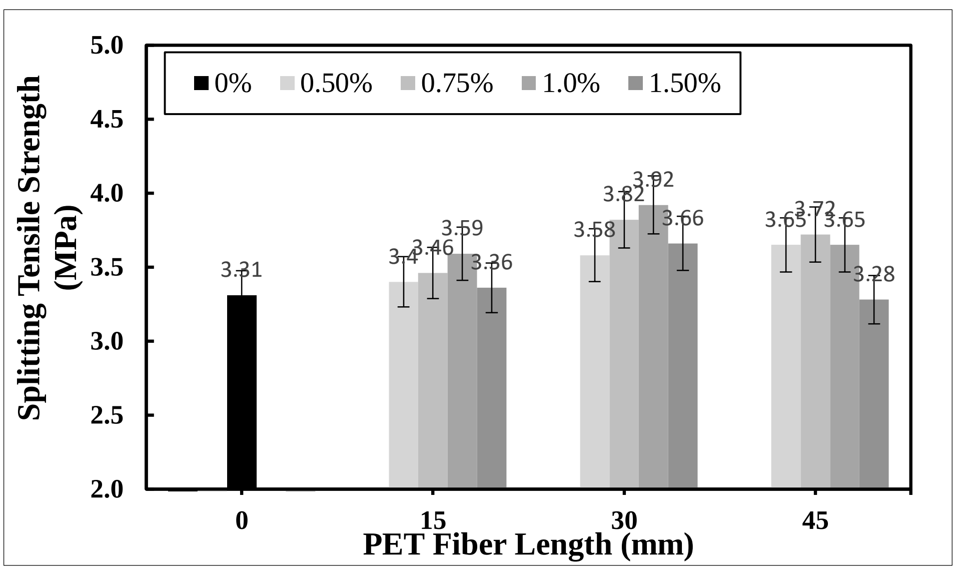


Figure 8. Variation of splitting tensile strength with PET fiber length

Figure 9. Bridging mechanism of PET fiber in the concrete matrix.

Based on the findings of this study and earlier research, increasing the amount of PET fibers up to 1% by volume of concrete mix, particularly using PET fibers with a length of 30mm, substantially enhanced the tensile strength. Hence, the addition of 1% of 30mm PET fibers is proposed as the optimal dosage for further investigations. This amount is considered to balance enhanced tensile strength with practical considerations and will be employed in the subsequent stages of the research. The subsequent procedures will thoroughly evaluate the modulus of rupture using various prism sizes to gain a comprehensive understanding of how this optimal dosage performs across different structural dimensions.

3.3. Modulus of Rupture and Size Effect

The modulus of rupture (f_r) of concrete (also known as flexural strength) is a measure of the maximum tensile stress that a beam can withstand before it fails in bending [19]. The size effect on fiber-reinforced concrete refers to the phenomenon that the mechanical properties of FRC, such as its compressive strength, flexural strength, and toughness, are influenced by the size of the concrete specimen [9]. The size effect on the modulus of rupture relates to how the modulus of rupture changes with the variations of size, particularly the depth, of the concrete specimen. Table 3 shows the average results of tests to assess the modulus of rupture of various prism sizes for three normal concrete grades of M45, M35, and M20 each containing 1% of 30 mm PET fiber. As stated before, the optimum fiber length and ratio were determined based on the test data given in this study. It can be observed clearly when the height of the prism changes from 100 to 200 mm, f_r decreases by a significant rate for all concrete grades as shown in Fig. 10. The f_r for the prism with 100 mm depth made of the C45 mix is 5.19 MPa being decreased by 18.50% and 21.58% when the depth changed to 150 mm and 200 mm respectively. Furthermore, the reduction of f_r caused by changing the prism depth from 100 mm to 200 mm is 23.71% and 24.44% for concrete grades of 35 and 20 MPa respectively.

This reduction of the modulus of rupture with increasing the prism's size while keeping all other parameters constant, such as concrete mix proportions is primarily attributed to the presence of inherent flaws and heterogeneities within the concrete matrix, which becomes more pronounced with larger specimen sizes [9]. As the specimen size increases, the probability of the presence of larger flaws, such as aggregates or voids, also increases. These flaws act as stress concentrators and can lead to the initiation and propagation of cracks under loading [28, 29]. Also, this reduction with size effect can be attributed to the fact that when the beam's size increases, the distance from the neutral axis (the axis where the stress acting on the section is zero) to the outer fiber increases. This results in larger tensile stresses in the outer fibers of the beam. Since concrete is weaker in tension, larger tensile stresses increase the likelihood of cracking in the beam. Cracks can develop earlier and propagate more easily in larger beams, leading to a lower modulus of rupture [29].

It can be observed from the current experimental data that the reduction ratio in f_r from 100 to 150 mm is higher than that occurred when the depth changed from 150 to 200 mm for all three concrete grades of M20, M35, and M45. Also, it is observed that the relation between f_r and the prism's depth is not linear. This behavior is also seen in the studies of Bazant and Planas [29]. Subsequently, it was observed that the effect of compressive strength on the modulus of rupture is significant. For example, for a prism depth of 100 mm, the modulus of rupture increases by 18.50% when the compressive strength increases from 33.05 MPa to 45.6 MPa. This improvement rate is even higher for deeper prisms. For a prism depth of 200 mm, the modulus of rupture increases by 21.58% when the compressive strength increases from 33.05 MPa to 45.6 MPa. The improvement in modulus of rupture with increasing compressive strength is due to the fact that the concrete matrix is better able to resist crushing at higher compressive strengths. This allows the PET fibers to be more effective in bridging cracks and resisting tensile stresses.

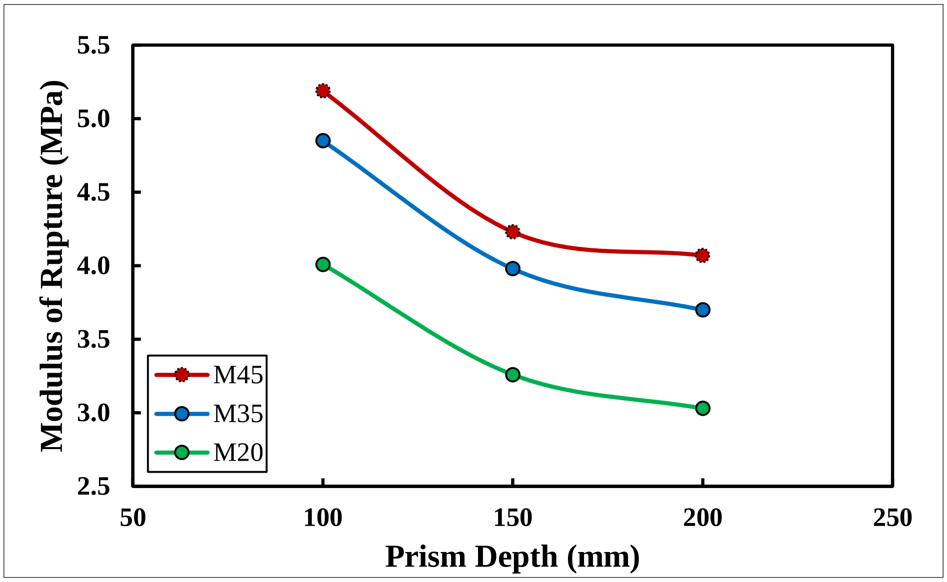


Figure 10. Variation of modulus of rupture with prism depth.

Table 3. Results of flexural strength for various concrete grades.

Mix No.	w/c	Compressive Strength (MPa)	Splitting Tensile Strength (MPa)	Prism Depth (mm)	Modulus of Rupture (MPa)
M1-100	0.45	45.60	4.42	100	5.19
M1-150				150	4.23
M1-200				200	4.07
M2-100	0.55	33.05	3.85	100	4.85
M2-150				150	3.98
M2-200				200	3.70
M3-100	0.70	21.80	3.16	100	4.01
M3-150				150	3.26
M3-200				200	3.03

3.4.Mode of failure

The cracking pattern of failed concrete cylindrical specimens indicates that the addition of PET fiber has no significant influence on the mode of failure in the compression test compared to the control specimens. Fig. 11 shows the real observation of the cylindrical specimens for different PET fiber volume fractions that were tested in compression, and Fig. 12 shows the failure observation of cylindrical specimens for different PET fiber lengths subjected to the compression test.

In the splitting tensile strength test, the concrete cylinders without PET fiber collapsed immediately after the concrete cracked, while it was found that the existence of PET fiber in concrete specimens can maintain their original shape even after the cracking of concrete. This demonstrates that the macro plastic fiber reinforced concrete can absorb energy in the post-cracking state [2,3]. In general, specimens containing PET fibers were found to be more capable of resisting the splitting load after failure without complete collapse. Fig. 13 and 14 shows the actual cylindrical specimen failure subjected to the splitting tension test.

Figure 11. Failure mode of specimens contained various PET fiber volumes under compression test.

Figure 12. Failure mode of specimens contained various PET fiber lengths under compression test.

Figure 13. Failure mode of specimens contained various PET fiber volumes under splitting tensile test.

Figure 14. Failure mode of specimens contained various PET fiber lengths under splitting tensile test.

Fig. 15 shows the flexural failure mode of various prism specimens concerning their size. Results indicate that prisms with lower depths (100 and 150 mm) are more prone to brittle failure, commonly referred to as brittle matrix failure. In this mode, the concrete matrix itself fails in a brittle manner, usually characterized by sudden and catastrophic cracking without much plastic deformation [3,10]. A single macro-cracking failure mode appears for a prism depth of 200 mm, in this mode, with an optimal amount of PET fibers, the prism exhibits a single macro crack at the center of the prism that distributes the applied load more evenly. This mode enhances energy absorption and toughness, as the fibers bridge the cracks and help maintain load-carrying capacity [30].

Figure 15. Failure modes of PET fiber concrete prisms

3.5. Prediction of Modulus of Rupture

Regression analysis is performed herein on the experimental data obtained in this study to predict equations for the modulus of rupture of the concrete section containing PET fiber, considering various prism sizes and compressive strengths. The following simple power equation is proposed for the modulus of rupture (f_r).

$$f_r = \alpha * x^{\beta} \quad (1)$$

In the above relationship, the independent variable *x* depends on both compressive strength (*fc'*) and prism depth (*h*). Several trials have been carried out to correlate x with the two properties and found that *x* is equal to $f'c^{0.9}/h$. Figure 16 shows the variation of the modulus of rupture with $f'c^{0.9}/h$ from which a strong relationship is observed. As shown in the figure, regression analysis will lead to the following equation:

$$f_r = 8.373 * \left(\frac{fc^{0.9}}{h}\right)^{0.401} \quad (2)$$

By simplifying Eq. (2), Eq. (3) obtains

$$f_r = 8.373 * \frac{fc'^{0.361}}{h^{0.401}} \tag{3}$$

In Eq. 3, the unit of *f'c* in MPa and h in mm.

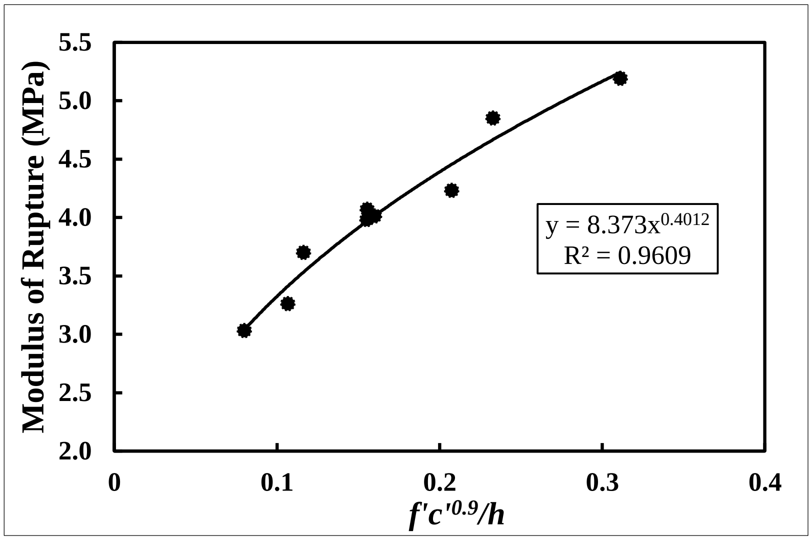


Figure 16. Relation between f_r and $f'c^{0.9}/h$.

4. Conclusion

The following conclusions can be made based on the laboratory experimentation and data analysis on the properties of concrete with PET fiber:

1. The addition of PET fibers resulted in a reduction in compressive strength ranging from 83% to 99.5% compared to the control concrete.

2. The compressive strength drop was more pronounced with increasing fiber volume and length. A 1.71% reduction occurred with 15 mm fibers at 0.5%, while a 16.93% reduction was observed with 45 mm fibers at 1.5%.

3. Fiber balling and potential incompatibility between plastic fibers and the concrete matrix were identified as contributors to the strength reduction.

4. Splitting tensile strength showed improvement, reaching up to 18.43% with 1% PET fibers of 30 mm length.

5. The performance of 30 mm fibers was superior to 15 mm and 45 mm fibers, indicating an optimal length for enhanced tensile strength.
6. A noticeable size effect on the modulus of rupture was observed, with an inverse relationship between specimen size and measured flexural strength.
7. As the size of the specimen increased, the flexural strength decreased. Reduction ratios ranged from 18.50% to 24.44% when prism depth increased from 100 mm to 200 mm across different concrete grades.
8. Larger specimen sizes increased the likelihood of flaws and heterogeneities, leading to stress concentrators and crack initiation.
9. PET fiber addition did not significantly influence the mode of failure in compression tests. The cracking pattern remained consistent with control specimens.
10. In splitting tensile tests, specimens with PET fibers demonstrated better post-cracking behavior, maintaining their original shape and resisting complete collapse.
11. Using regression analysis between the independent variables (compressive strength and depth of prism) and dependent variable (modulus of rupture), an equation with R^2 of 0.96 was developed to predict the modulus of rupture of concrete containing PET fiber.

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تقييم تأثير حجم العينة على مقاومة الانثناء للخرسانة الحاوية على الياف البولي أثيلين تيرافثاليت بالمحتوى الامثل

الخلاصة :تستكشف هذه الدراسة تأثير حجم العينة على القوة الانحنائية للخرسانة المعززة بألياف بولي إيثيلين تيريفثاليت (PET) المحسّنة .تم إجراء سلسلة من الاختبارات التجريبية باستخدام كميات مختلفة من ألياف) PET من 0 .5إلى 1 5٪ بالحجم) وأطوال (15 و 30 و 45 مم) لتسليط الضوء على ألياف PET المحسنة في الخرسانة .تم إجراء اختبارات القوة الانحنائية على عينات منشوريه بأحجام مختلفة (100 × 100 × 400 مم ، 100 × 150 × 500 مم ، و 100 × 200 × 700 مم) ودرجات مختلفة من الخرسانة (20 ، 35 ، و 45 ميجا باسكال) .تشير النتائج إلى تحسن كبير في القوة الشديدة للخرسانة، حيث تصل إلى 18.43% بإضافة ألياف .PET تعمل هذه الألياف بشكل فعال كجسور عبر الشقوق ، مما يقلل من عرضها ويوقف انتشارها .تم تحديد طول ألياف PETالأمثل بأنه 30 مم، ويضاف إلى الخرسانة بنسبة 1٪ من حجم الخليط .كشفت النتائج عن تأثير حجم ملحوظ على القوة الانحنائية للخرسانة المعززة بأليافPET، مع علاقة عكسية بين حجم العينة والقوة الانحنائية المقاسة .كلما زاد حجم العينة، انخفضت القوة الانحنائية .بناءً على البيانات التجريبية، تم تطوير علاقة تجريبية لتحديد القوة الانحنائية للخرسانة المعززة بألياف PET المحسنة مع الأخذ في الاعتبار تأثير الحجم .توفر هذه العلاقات أدوات عملية للمهندسين لحساب تأثير الحجم بدقة في تصميم وتحليل هياكل الخرسانة المسلحة بالألياف .

الكلمات الدالة: *ألياف بولي إيثيلين تيريفثاليت*، مقاومة الانضغاط، تقسيم قوة الشد، قوة الانحناء، تأثير الحجم، تحليل الانحدار.