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EXPERIMENTAL INVESTIGATION OF HIGH-STRENGTH POLYMER-MODIFIED CONCRETE INCORPORATING SBR LATEX, WASTE CRUMB RUBBER, AND PET FIBERS

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ABSTRACT

The present work aims at investigating the behavior of high-strength polymer-modified concrete (PMC) using styrene-butadiene rubber (SBR) latex, waste crumb rubber (WCR), and polyethylene terephthalate fibers. The primary goal is to assess the influence of these materials on workability, mechanical properties, durability, and microstructure. Different concrete groups were generated with different percentages of SBR latex, WCR, and PET fibers ratios, with the constant w/b of 0.42. The experimental approach adopted the ASTM codes for materials testing, including workability tests (slump, compaction factor), mechanical property tests (compressive and splitting tensile strength), to determine durability parameters like water penetration, sorptivity, and chloride permeability. The curing ages were 7, 28, 56, and 91 days for the mixes. The results revealed that the inclusion of PET fibers at 20% added a beneficial effect on compressive strength (up to 60 MPa at 91 days) and tensile strength (up to 5.3 MPa at 91 days), as compared to the control mix. Performance tests have shown that the resistance to water penetration, sorptivity, and chloride ion penetration are considerably better for these concretes containing 20% PET fibers almost ranked in "excellent" durability level. SEM analysis also validated the presence of better fiber-cement matrix bonding that resulted in improved crack resistance and lower porosity. Finally, using SBR latex in combination with WCR and PET fibers for HSC provides an environmentally friendly and practical alternative to enhancing the mechanical and durability properties of concrete, which could be a promising solution to sustainable construction materials. The findings indicate that a content of 20% PET fiber is the best from the strength, workability, and durability point of view.

Keywords: *Polymer-modified concrete, SBR latex, waste crumb rubber, PET Fibers, durability*

1. INTRODUCTION

The production of ecological, efficient, and high-strength building materials is a top priority for contemporary civil engineering. Traditional concrete is constrained with brittle, rather low tensile strength, and can crack or be damaged by the environment (Kovler & Roussel, 2011). To circumvent these drawbacks, the use of polymer-modified concrete (PMC) has gained relevance and become one of the most promising materials with a proper mix proportion between cement that absorbs the energy, while the flexible nature ensures damping properties (Islam et al., 2011). Among the polymer modifiers, SBR latex has been identified as an effective design to enhance both mechanical strength and durability. Hatungimana et al. (2020) showed that the addition of 10% SBR latex by the binder weight increased compressive strength from 46 MPa to 53 MPa (15% increase) and decreased water absorption by 25%. Similarly, Kocak et al. (2022) reported an increase in flexural strength by 22% as well as better surface cohesion of the polymer film through SBR latex impregnation in the cement matrix.

In addition to polymer modification, the use of recycled materials such as waste crumb rubber (WCR) and polyethylene terephthalate (PET) Fibers leads to environmentally sustainable and more ductile pavement (Zahid et al., 2025). Hisbani et al. (2025) showed that the replacement of 10% fine aggregate by crumb rubber induced an 18% reduction in the compressive strength (from 50 MPa to 41 MPa), but also a benefit on impact and strain capacity increase of approximately 35%. Mohammed and Mohammed (2021) indicated that concrete with 0.5% of PET Fibers increased in splitting tensile strength by 25% and showed a fine cracking pattern as compared to plain concrete. These results indicate that the hybrid addition of SBR latex, WCR, and PET Fibers can lead to an optimized improvement of strength, elasticity, and durability.

The properties of modified concretes are determined by grouping fresh, mechanical, and durability characteristics. The workability is important for compaction in construction as well as the uniform quality of the material. Shabaan (1989) noted that the addition of 5% SBR latex decreased the slump from 90 to 70 mm on account of higher viscosity. Majeed Abed et al. (2024) also reported that the mixtures with 10% crumb rubber and 0.5% PET Fibers reduced of 15% the slump values but with better cohesiveness between mixture components. Also, compacting factor values were between 0.86 and 0.90, indicating good workability for vibration compaction. Kelly's ball penetration tests by Ferraris demonstrated that polymer-modified concretes are stiffer than reference mixes relative to control gauge (18-20 mm vs 25 mm), at the early stage of mixing. Compressive and tensile strengths are important parameters that indicate the structural performance. Yahya (2015) reported compressive strengths (up to 58 MPa) at 28 days for concretes containing 10% SBR compared with the control (48 MPa). PET Fiber inclusion also led to improved post-cracking performance, promoting toughness indices up to 30% (Wang et al., 2025). These enhancements originate from the synergetic effect of more effective interfacial bonding and better confinement in the matrix. Alipourlashkarian (2019) found a good correlation between ultrasonic pulse velocity (UPV) and compressive strength, that concretes with UPV 4.3–4.5 km/s can produce a compressive strength range of 55 to 60 MPa. Ashraf et al. (2022) reported that UPV of SBR-modified concretes was measured to be beyond 4.2 km/s, capturing densification. Likewise, the rebound hammer value increased from 35 to 42 by applying SBR latex and fibers due to better surface hardening as well as compactness.

Durability is an important consideration in the life of HPCs. Idrees et al. (2022) also reported an approximately 35 to 40% reduction in chloride permeability at the age of 56 days using an SBR-based modified binder through the RCPT test, i.e., charge passed reduced from 2800 (control) to ~1700C. Ismail et al. (2009) inference that SBR-modified concrete showed a 30% reduction in WA and a 25% reduction in sorptivity when compared with that of control specimens. Crumb rubber inclusion improved resistance to microcracking and freeze–thaw damage; the penetration depth of water was decreased from 18 mm to 12 mm due to the presence of PET Fibers (Iqbal et al., 2024). These findings verify that the unification of polymer latex, rubber, and fibers greatly improves impermeability and durability. These enhancements in performance have been corroborated by microstructural investigations. SEM and EDS results provided by Yang et al. (2009) showed that SBR latex adds a homogeneous polymer region in the mix, diminishing pore connectivity and densifying ITZ. It was found that at early ages, the presence of crumb rubber and PET Fibers closed micro-voids when bridging cracks, which led to a denser and more uniform matrix. The decrease in porosity and greater bonding account for this increased strength, water, and chloride resistance as observed from experimental data.

However, according to the literature review, little attention has been given to the combined impacts of SBR latex, WCR, and PET Fibers on fresh-state property, mechanical behavior, durability, and microstructure of high-strength concrete yet. Prior research typically concentrated on single modifiers or binary hit pairs, leaving their synergistic impact largely unanalyzed. Accordingly, this research aims to experimentally investigate the synergistic effect of SBR latex, crumb rubber and PET Fibers on both workability, in addition to strength durability and microstructure of high-strength polymer-modified concrete. It is aimed to contribute to a sustainable and durable concrete making use of recycled materials without sacrificing mechanical strength.

2. METHODOLOGY

The characterization and testing of all materials involved (cement, aggregates, SBR latex, WCR (waste crumb rubber), and PET (polyethylene terephthalate) Fibers were carried out in compliance with the corresponding ASTM standards to evaluate their suitability for the production of high-strength concrete.

1.1 Materials

Ordinary Portland cement (OPC), type I, which is available in the local markets, was used to mix all batches of concrete. The cement met the specifications of ASTM C150 to ensure uniform quality and performance (Choudhary et al., 2022). Natural river sand taken from Khulna Rupsha ghat, Bangladesh. The sand was washed, oven-dried, and then sieved by the standard sieve series in the KUET materials laboratory. The physical properties of the materials, such as the specific gravity, fineness modulus, water absorption, and dry rodded unit weight, were tested following ASTM C128 (Gómez-Cano et al., 2022) and ASTM C29 (Concreate, 2017). 2.96, 2.2% and 1630 kg/m per cubic meter for fineness modulus, water absorption, and dry rodded unit weight, respectively. The coarse aggregate used was crushed stone obtained from a local source. The material was washed, dried, and sieved to the desired particle size distribution. The physical features, including specific gravity, water absorption, Fineness Modulus (FM), and Dry Rodded Unit Weight, were determined in accordance with the ASTM C127 and ASTM C128 (Fournari & Ioannou, 2019). Synthetic polymer emulsion, namely styrene–butadiene rubber (SBR) latex, was used as a modifier to enhance workability, bond strength, durability, and flexibility of concrete. Latex was obtained from a local chemical supplier in Dhaka, Bangladesh. It was about 48–50% solids, had a pH of 9 to 10, and its specific gravity was approximately 1.02 gm/cc (Lobo, 1991). The SBR latex was incorporated into some of the mixes as a percentage of the binder weight to improve mechanical and durability properties through the formation of a polymer film within the cementitious matrix. Waste crumb rubber from scrap vehicle tyres was also partially replaced with fine aggregates. Secondary reinforcements were achieved by the incorporation of PET Fibers, derived from recycled plastic bottles, in order to enhance the tensile strength and crack resistance. The mechanical properties reported by the manufacturer were a specific gravity of 1.35 g/cm³, tensile strength of 600 MPa, and an elastic modulus of 7.5 GPa. These fibres were added to low volume fractions of concrete to enhance ductility and after-cracking performance. Table 1shows the chemical characteristics of cement and SBR Latex. Table 2 shows the physical characteristics of the aggregates. Table 3 shows the physical characteristics of PET Fiber.

Table 1: Chemical Characteristics of Cement and SBR Latex

Chemical Oxides	Cement	SBR Latex
		Property-Typical Range / Behavior
CaO	61.18	Physical Form- Milky-white aqueous emulsion
SiO_2	21.65	Chemical Nature- Styrene-Butadiene copolymer latex
Al_2O_3	6.12	pH- ~8–11 (alkaline)
MgO	1.05	Solid Content- ~48–55%
Fe_2O_3	4.19	Particle Size- ~0.1–0.2 µm

Na_2O	1.32	Ionic Character- Anionic
SO_3	2.93	Glass Transition Temperature- Approximately −20°C to +5°C
P_2O_5	—	Stability- Stable in alkaline media; unstable in acids
SrO	—	
Cl	0.17	

Table 2: Physical Characteristics of the Aggregates

Characteristics	**Fine Aggregate**	**Coarse Aggregate**
Specific Gravity	2.66	2.95
Absorption (%)	2.2	2.35
Fineness Modulus	2.96	6.4
Dry Unit Weight (kg/m^3)	1630	1582

Table 3: Physical Characteristics of PET Fiber

Characteristics	**Values for PET Fibers**
Diameter (mm)	Approximately 4
Length (mm)	Typically 20
Thickness (µm)	Around 12 – 25
Density (g/cm^3)	About 1.34 – 1.40
Tensile Strength (MPa)	Roughly 600 – 900
Young's Modulus (N/mm^2)	Nearly 8000 – 12000

1.2 Mixture and proportions

Up to eight concrete batches, one control, and seven modified with SBR latex, WCR, and PET Fibers were cast. The water/binder (W/B) of all mixes remained 0.42 to achieve uniformity. The mix design was carried out as per ACI 211.4R-93 (Venkatesh & Arun, 2016). The control mix was composed of 100% cement without any additives. For the modified mixtures, 5%, 10%, 15%, 20% and 25% weight percent of SBR latex was supplemented with respect to the cement and used in M-5%, M-10% and M-15%, respectively; the WCR replaced 10% fine aggregates by weight. The proportion of PET Fibers used in this study is 1% by volume of concrete. The specific mix proportions are presented in Table 4.

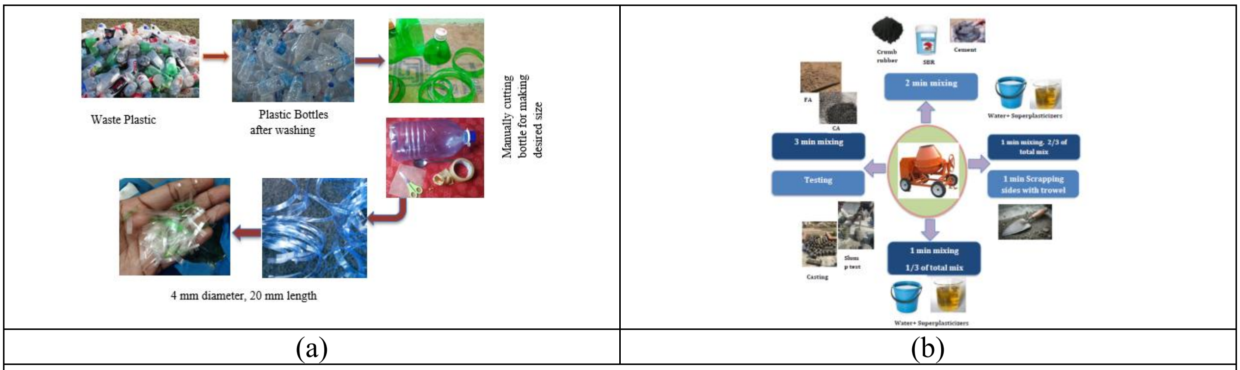
Table 4: Concrete Mix Design (kg/m^3)

Mix ID	**% of replacement of polymer**	**Cement Kg/m^3**	**SF %**	**FA Kg/m^3**	**Crumb Rubber % replacement**	**CA Kg/m^3**	**W/B**	**Water Kg/m^3**	**PET fiber % replacement**	**SP%**
Control-M1	0	442.11	10	400.33	0	785.32	0.42	190.08	0	1.2
M2-PET1%CR0%P0%	0	442.11	10	400.33	0	785.32	0.42	190.08	1	1.2
M3-PET0%CR10%P0%	0	442.11	10	400.33	10	785.32	0.42	190.08	0	1.2

M4-PET1%CR10%P5%	5	442.11	10	400.33	10	785.32	0.42	190.08	1	1.2
M5-PET1%CR10%P10%	10	442.11	10	400.33	10	785.32	0.42	190.08	1	1.2
M6-PET1%CR10%P15%	15	442.11	10	400.33	10	785.32	0.42	190.08	1	1.2
M7-PET1%CR10%P20%	20	442.11	10	400.33	10	785.32	0.42	190.08	1	1.2
M8-PET1%CR10%P25%	25	442.11	10	400.33	10	785.32	0.42	190.08	1	1.2

1.3 Preparation of Specimen, Casting, and Curing

All samples complied with ASTM C192 (ASTM, 2007). The dry mix was blended completely, and then SBR latex and water were added to homogenize the distribution of polymer and other components. The new, fresh concrete was cast inside steel molds (previously lubricated) having the same identification as the mix. Specimens were demolded after 24–36 h and then placed in a curing tank filled with potable water at ambient temperature. The curing durations were kept at 7, 28, 56, and 91 days for the examination of early and long-term characteristics. Figure 1 shows (a) Preparation of PET Fiber, (b) Preparation of Specimen and Casting.



(a) (b)

Figure 1: (a) Preparation of PET Fiber, (b) Preparation of Specimen and Casting

1.4 Test Setup and Instrumentation

The workability of the mixtures was evaluated by standard tests. The consistency of the mix was determined by the slump test according to ASTM C143/C143M (Standard, 2015).The relative compaction with gravity was determined by the compacting factor test as per BS EN 1881 (Institutions, 1881). The Kelly ball test was employed as a simple check on workability and surface texture. By performing these tests, each mix was able to achieve an adequate workability for a proper placement and finish.

Mechanical behavior was characterized by compressive strength and splitting tensile strength experiments. Compressive strength was tested at the ages of 7, 28,56, and 91 days according to ASTM C39/C39M for cube specimens (Testing et al., 2021). Splitting tensile strength test was carried out on cylindrical specimens (100 mm × 200 mm) according to ASTM C496/C496M (ASTM, 2017).

Durability was also analyzed to determine the resistance of modified concretes to fluid and chemical penetration. The following tests were conducted: Sorptivity Tests (ASTM C1585) (Akid et al., 2023) Water penetration Test, according to BS EN 12390-8, for permeability depth under pressure. Rapid Chloride Penetration Test (RCPT) according to ASTM C1202 for the determination of resistance against chloride ion penetration. Microstructure analysis (SEM) to investigate pore structure, ITZ development, as well as the influence of polymer film formation.

3. RESULTS AND DISCUSSIONS

1.4.1 Fresh Properties

The results of the workability test shown in Figure 2 indicate uniform growth of slump value, ball penetration depth, and compaction factor with increasing PET proportion. The base mix exhibited the lowest slump of about 75-80 mm, ball penetration depth of around 70-75 mm, and compaction factor close to 0.97; thus, workability is considered normal. On the contrary, indicate, PET mixes showed high workability levels; slump value reached 85-95 mm for 10% of PET and up to 120-130 mm for up to 30% of PET; the same trend was recorded for ball penetration depth, ranging from 95-105 mm for lower PET levels to 135-145 mm for up to 30% of PET. Similarly, the compaction factor was about 1.0-1.1 for a moderate level of PET and 1.6-1.7 for 30% PET, which indicates easier compaction and high flowability. The increased workability can be explained by a smooth surface texture and hydrophobic nature of PET particles, which reduces friction due to water reduction and limits paste absorption during mixing. Nonetheless, the acute rise in workability at a higher PET rate and dosage exceeding 30% reveals the risk of segregation and bleeding due to a lack of cohesion. Agrawal et al. (2024) reported similar findings, affirming that polymer-based waste addition leads to increased workability by lowering internal friction and changing the matrix flow. Therefore, the present results confirm that the incorporation of PET improves workability and suggest that 20% PET offers an optimal balance between improved mix flow and increased mix cohesion.

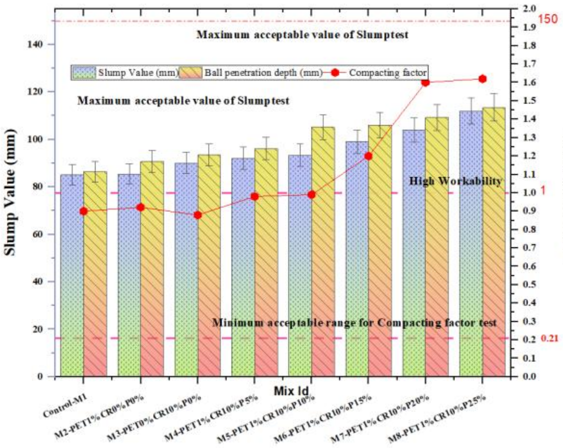


Figure 2: Workability test: slump test, ball penetration depth, and compaction factor test.

1.4.2 Mechanical Properties

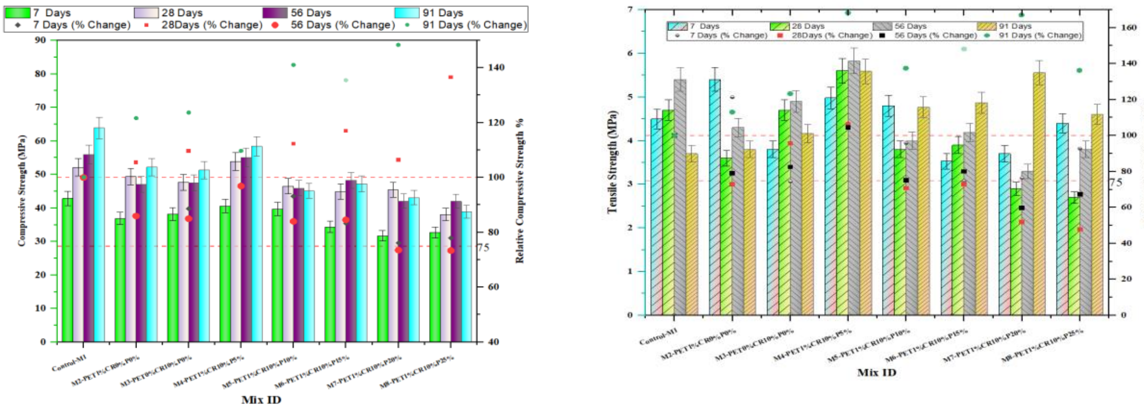
Figure 3(a) shows the development of compressive strength of the pet waste concrete at 7, 28, 56, and 91 days. The strength values are roughly about 36 MPa, 45 MPa, 52 MPa, and 55 MPa of the control mix at 7, 28, 56, and 91 days, respectively. However, PET incorporation showed an initial improvement of strength when added at a moderate percentage, as shown in M6, where 20% PET reached approximate values of 38-40 MPa, 48-50 MPa, 55-58 MPa, and about 60 MPa at 7, 28, 56, and 91 days, respectively. This improvement is attributed to the safety of the pet waste to micro-crack propagation and better hydration and crack-bridging capability. At higher mixes beyond 20% PET showed the strengths deteriorated up to about 28-33 MPa at 28 days and 40-45 MPa at 91 days due to the formation of voids and weakening of the matrix interfacial bond between the PET plastic particle with the cement paste. The 20% pet is thus the optimum percentage. Figure 3(b) depicts the tensile performance of PET waste concrete at about 7, 28, 56, and 91 days. The control mix attained about 2.9 MPa, 3.8 MPa, 4.2 MPa, and 4.4 MPa, respectively. However, M6 demonstrated the best tensile performance, reaching about 3.2-3.4 MPa, 4.4-4.6 MPa, and about 5.0-5.3 MPa at 7, 28, and 91 days, respectively. Since the particle positively affects post-cracking resistance by limiting the crack widths, hence an increase in tensile resistance. Overall, Figure 3 shows that there is improved mechanical performance at up to 20% PET, which is the most recommended percentage.

Table 5: Compressive Strength (MPa)

Mix ID	Curing Age (Day)	Mean Strength (MPa)	Standard Deviation	Coefficient of Variation	Standard Error	Lower bound	Upper bound	Margin of Error
Control	7	41.87	0.27	0.64	0.16	41.56	42.18	0.31
	28	52.12	1.07	2.05	0.62	50.91	53.33	1.21
	56	55.15	0.90	1.63	0.52	54.13	56.17	1.02
	91	6483	0.45	0.01	0.26	6482.49	6483.51	0.51
PET	7	36.11	0.31	0.86	0.18	35.76	36.46	0.35
	28	40.18	0.64	1.59	0.37	39.46	40.90	0.72
	56	48.51	0.87	1.79	0.50	47.53	49.49	0.98
	91	41.47	0.98	2.36	0.57	40.36	42.58	1.11
CR	7	39.1	1.20	3.07	0.69	37.74	40.46	1.36
	28	49.32	0.33	0.67	0.19	48.95	49.69	0.37
	56	46.01	0.34	0.74	0.20	45.63	46.39	0.38
	91	53.51	0.84	1.57	0.48	52.56	54.46	0.95
P5%	7	40.51	0.59	1.46	0.34	39.84	41.18	0.67
	28	53.67	0.42	0.78	0.24	53.19	54.15	0.48
	56	54.11	0.78	1.44	0.45	53.23	54.99	0.88
	91	58.22	0.76	1.31	0.44	57.36	59.08	0.86
P10%	7	39.01	0.76	1.95	0.44	38.15	39.87	0.86
	28	46.32	0.54	1.17	0.31	45.71	46.93	0.61
	56	46.92	0.45	0.96	0.26	46.41	47.43	0.51
	91	45.27	0.23	0.51	0.13	45.01	45.53	0.26
P15%	7	34.86	0.54	1.55	0.31	34.25	35.47	0.61
	28	44.45	0.23	0.52	0.13	44.19	44.71	0.26
	56	47.23	0.12	0.25	0.07	47.09	47.37	0.14
	91	47.12	0.54	1.15	0.31	46.51	47.73	0.61
P20%	7	31.89	0.63	1.98	0.36	31.18	32.60	0.71
	28	45.23	1.04	2.30	0.60	44.05	46.41	1.18
	56	41.06	0.38	0.93	0.22	40.63	41.49	0.43
	91	43.01	0.44	1.02	0.25	42.51	43.51	0.50
P25%	7	32.65	0.51	1.56	0.29	32.07	33.23	0.58
	28	38.09	0.39	1.02	0.23	37.65	38.53	0.44
	56	40.98	0.13	0.32	0.08	40.83	41.13	0.15
	91	38.87	0.79	2.03	0.46	37.98	39.76	0.89

1.4.1 Durability

Figure 4 reveals that adding PET waste Fibers enhances the durability performance of concrete when compared to the control mix. As shown in Figure 4, the control concrete had the highest water penetration depth of about 30 mm, sorptivity of approximately 35×10-6 g/mm^2 /min$^{1/2}$, and RCPT charge of between 2000 and 2200 coulombs, showing a more porous matrix prone to chloride attack. The PET-reinforced mixes, on the other hand, demonstrated major improvements as a result of the fibres' ability to reduce the formation of micro-cracks, shrinkage cracking, and increase the tortuosity of transfer pathways in the cement matrix. The 20% PET mix attained the best performance, with the lowest water penetration, sorptivity, and RCPT values averaging about 13 mm, 18×10-6 g/mm^2 /min$^{1/2}$, and 900 coulombs, respectively, placing it in the "excellent" durability category. As can be observed in Figure 4, mixes with 10% PET also outperformed the control with penetration values of 15-22 mm, sorptivity around 28-30 ×10-6, and RCPT values of 1200-1500 coulombs. However, durability worsened as PET content increased further, with water penetration climbing to 22-28 mm, sorptivity increasing to 30-36 x10 -6, and RCPT values spiking to 1800-2000 coulombs due to fibre agglomeration, reduced workability, and increased voids. Priya and Thirumalini (2018) found that optimum fiber levels reduce water absorption, sorptivity, and chloride permeability drastically. Similarly, More and Subramanian (2022) reported that artificial fibers, when correctly dosed, reduced sorptivity and RCPT compared to conventional concrete. In conclusion, 20% PET is the optimal dose, offering the best resistance to water and chloride entry in the investigated aggregates, revealing the most effective and environmentally benign approach to enhance durability.



(a)

(b)

Figure 3: Mechanical properties test, (a)Compressive strength test, (b)Tensile strength test

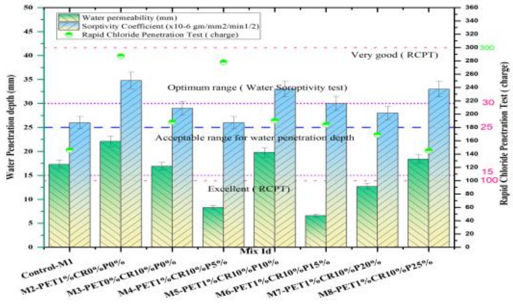
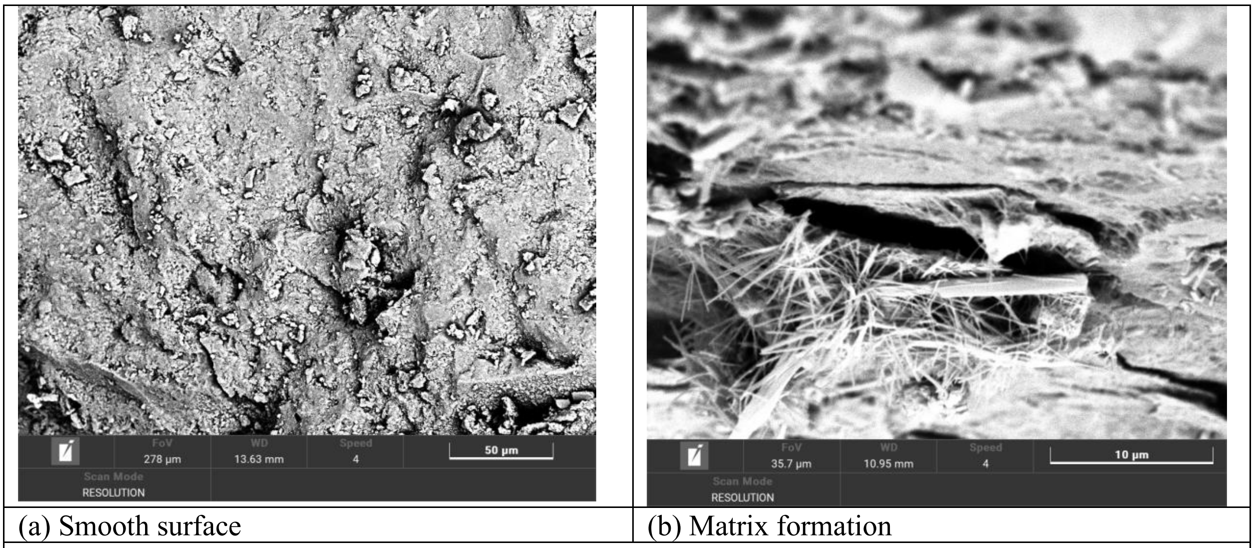


Figure 4: (a) Preparation of PET Fiber, (b) Preparation of Specimen and Casting

1.4.2 Scanning Electron Microscopy

The SEM views of the PET-modified concrete microstructure are depicted in Figure 5. Figure 5(a) displays the surface profile of concrete, which seems relatively smooth and dense, with scant surface micro-voids. The morphological feature implies the effective hydration and formation of calcium-silicate-hydrate gel and the weakened continuity among individual pores, which is congruent with the early findings of enhanced mechanical and durability properties. In contrast, the intra-matrix configuration, fiber fusion, and entwinement among PET particles and cementitious stages are depicted in Figure 5(b). In the SEM image, fibrous forms and alternating structures with PET filaments embedded within the matrix and properly bonded with the surrounding phase are observed. The morphology demarcates micro-crack bridging and arrest due to filament interlocks, restraining crack span and improving the internal opposition of the material to tension, thereby enhancing the strength and swelling potential. The noticed micro-bridging between PET and the matrix-increased vacuum eliminates micro-voids, corroborating the fact that PET enhancement fosters a more matrix pliability for enhanced functionality. Thus, the SEM examination validates the findings that PET injection boosts microstructure characteristics by facilitating denser hydration artifacts and improving the fiber-matrix affinity for improved concrete performance.



(a) Smooth surface

(b) Matrix formation

Figure 5: (a) Preparation of PET Fiber, (b) Preparation of Specimen and Casting

CONCLUSIONS

This research presents synergy among SBR latex, waste crumb rubber (WCR), and polyethylene terephthalate (PET) Fibers to control the properties of high-strength polymer-modified concrete (PMC). Their effect on workability, mechanical strength, durability, and microstructure was investigated are given below:

- The workability of the mixes was enhanced due to the addition of PET fibres, where an observable rise in slump value, ball penetration and compaction factor was noticed. For low PET content (up to 20%), the workability was well compromised, showing compaction ease and flowing properties with little segregation and bleeding issues.

- The enhancement of compressive and tensile strength was high with 20% addition of PET Fibers. The 20% PET mix reached compressive strength of approximately 60 MPa at 91 days, versus the 55 MPa achieved by the control mix. From the results, the tensile strength increased from 4.4 MPa in the control mix to 5.3 MPa at 91 days for the 20% PET mix indicating improved post-cracking resistance.

- The 20% PET mixture possessed excellent durability, showing characteristics of lower depth of water penetration (13 mm), sorptivity (18×10^{-6} g/mm²/min½), and Rapid Chloride Penetration Test (RCPT) values (900 coulombs), representing better resistance against water and chloride penetration. The control mix resulted in higher results for these durability indicators at 354 days, emphasizing the enhancement due to including PET Fibers.

- SEM images substantiated the increase in matrix densification and crack-bridging by the PET Fibers, which led to higher mechanical performance and durability of the concrete. The polymer film from SBR latex also allowed for better bonding and less porosity in the matrix, hence improving the overall performance.

Limitations

The research examined PET Fiber concentrations ranging from 0% to 25% by volume, excluding higher dosages. There were no changes made to other polymer modifiers or fiber types, which made it hard to apply the findings to other material systems. The long-term durability of the material under freeze-thaw cycles or harsh chemical exposures was not assessed.

Future Directions

- Test higher doses of PET Fibers and different polymer/fiber hybrids to find the best PMC performance.
- Test the long-term durability of the material by putting it through freeze-thaw cycles and chemical attacks.
- Use microstructural and phase analyses (like XRD/EDS/TGA/MIP) to learn more about how polymers, fibers, and cement interact.
- Look at how much it costs to use recycled-based PMC systems and how they affect the environment.

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DECLARATION OF USE OF AI

For writing this manuscript, the authors did not use any AI.

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