

Effect of Polyethylene Terephthalate (PET) Fibers on Concrete Properties

Koudzo ASSAGBAVI¹, Kouandété Valéry DOKO¹, Djidoula TAKO²

¹Laboratoire d’Énergétique et de Mécanique Appliquée (LEMA), Ecole Polytechnique d’Abomey-Calavi, Université d’Abomey Calavi (UAC), Abomey-Calavi, BENIN

²Institut de Formation Technique Supérieure (IFTS), Lomé-TOGO

Corresponding Author: Koudzo ASSAGBAVI

DOI : <https://doi.org/10.52403/ijrr.20250910>

ABSTRACT

This study aims to evaluate the effect of PET fibers, incorporated as a volumetric replacement of sand (0–3%), on the behavior of concrete, in order to identify a dosage range that provides optimal performance. The reference concrete mix was designed using the Dreux–Gorisse method, without the addition of admixtures or reinforcement. This mix served as the basis for the fiber-reinforced concretes. The PET fiber contents investigated were 0, 0.5, 1, 1.5, 2, 2.5, and 3% (0% corresponding to the plain control concrete). Fibers were introduced by volumetrically replacing sand with PET fibers. The water-to-cement ratio was kept constant at 0.55, with a cement dosage of 350 kg/m³.

The fibers were obtained from post-consumer plastic bottles and cut into strips 1–2 mm in width and 30–50 mm in length. The experimental program included the slump test (Abram’s cone), fresh concrete density, water absorption (0–192 h), water loss (24–192 h), and mechanical tests in compression and splitting tensile strength at 7 and 28 days.

Slump decreased from 6 cm (0 to 0.5%) to 3–3.5 cm ($\geq 2\%$). Density declined almost linearly between 0 and 3% (–6% in the fresh state and –9% in the hardened state). Water absorption reached a minimum at 1.5% (~0.25%) before increasing sharply beyond

2%, with saturation occurring between 144 and 192 h. Water loss reached zero around 144 h, with the longest terminal phase observed at 2.5%. In terms of mechanical performance, splitting tensile strength peaked at 1% (6.94 MPa at 7 days and 8.70 MPa at 28 days), while compressive strength peaked at 2% (18.26 MPa at 7 days and 27.19 MPa at 28 days). Beyond 2–2.5%, the combined effects of low workability and reduced compactness (due to ITZ weakening and entrapped air) negatively affected density, water absorption, and mechanical strengths.

Keywords: fiber-reinforced concrete, recycled PET fibers, sand replacement, water absorption, density, mechanical properties

1. INTRODUCTION

According to the OECD, global plastic production and waste generation have more than doubled since 2000. Production increased from approximately 234 million tonnes to 460 million tonnes, while waste rose from 156 million tonnes to 353 million tonnes in 2019. Only 9% of the 353 million tonnes of waste were effectively recycled after accounting for losses, whereas around 22% were mismanaged or leaked into the environment [1]. The United Nations Environment Programme reports that each year, between 19 and 23 million tonnes of

plastic waste enter aquatic ecosystems (rivers, lakes, and seas), illustrating both the magnitude of the challenge and the urgency of establishing an effective circular economy [2].

Among plastics, polyethylene terephthalate (PET) from beverage bottles represents a major, abundant, and relatively homogeneous resource. However, existing recycling channels are unable to keep pace with the growing volumes and often struggle to maintain consistent quality in recycled materials over time. This has led to increasing interest in high value-added recovery routes, particularly in cementitious materials. The incorporation of PET fibers can help control cracking, increase ductility, and, in some cases, improve durability-related indicators for such materials [3].

Recent studies indicate that the addition of recycled PET fibers simultaneously affects workability, compactness, and mechanical performance. Mouna et al. (2024) demonstrated that the combined optimization of fiber content and geometry enhances ductility and reduces shrinkage, while warning against high dosages that hinder workability [4]. Similarly, the work of Özaşık and Eren (2022) on concrete reinforced with recycled PET fibers confirmed improvements in tensile strength (splitting/flexural) at low to moderate dosages, at the cost of reduced slump. At higher dosages, fiber dispersion becomes challenging and compaction less effective [5]. More broadly, recent reviews emphasize that fibers (of all types) improve tensile strength and toughness but require precise rheological control to avoid

entrapped air and degradation of the paste–fiber interfacial transition zone (ITZ) [3].

Within this context, the present study focuses on the « *Utilization of Polyethylene Terephthalate (PET) Plastic Waste in Concrete* ». Its objective is to assess the influence of PET fibers on selected physical and mechanical properties, with the aim of identifying a viable dosage range.

II. MATERIALS & METHODS

II.1. Materials

A CEM II B/L 32.5 R Portland cement, produced in Togo by the CIMTOGO plant (Heidelberg Cement Group), with a density of 3100 kg/m³, was used throughout this study. No specific additives were introduced in order to avoid any potential reactions with the plastic waste. A rolled sand (SR 0/5) was used as the fine aggregate. This sand was sourced from Goumoukopé, a village in the canton of Aného, Lacs Prefecture (Maritime Region, Togo). Located on the northern shore of Lake Togo, the village lies along National Road No. 2, less than 500 m east of the Aného toll station, and about 40 km east of Lomé.

The coarse aggregate used was a crushed gravel (5/25 mm), supplied by the Lilikopé quarry, operated by TOGO-CARRIÈRE since 2006. Located in Zio Prefecture, this quarry lies 10 km south of Agbélouvé and 52 km north of Lomé, along National Road No. 1.

The particle size distributions of both sand and gravel were determined by sieving, in accordance with standard NF P 18-560. The results are presented in Figure 1 and Table 1.

Table 1: Physical properties of sand and gravel

Properties	Sand SR (0/5)	Gravel (5/25)
Absolute density (g/cm ³)	2.64	2.765
Bulk density (g/cm ³)	1.69	1.42
Water content (%)	6.44	–
Sand equivalent (%)	86.53	–
Coefficient of curvature	1.09	1.67
Coefficient of uniformity	3.67	3.75
Fineness modulus	1.97	–
Methylene blue value (VBS)	1	–
Los Angeles abrasion (%)	–	39.54
Flakiness index (%)	–	17.97

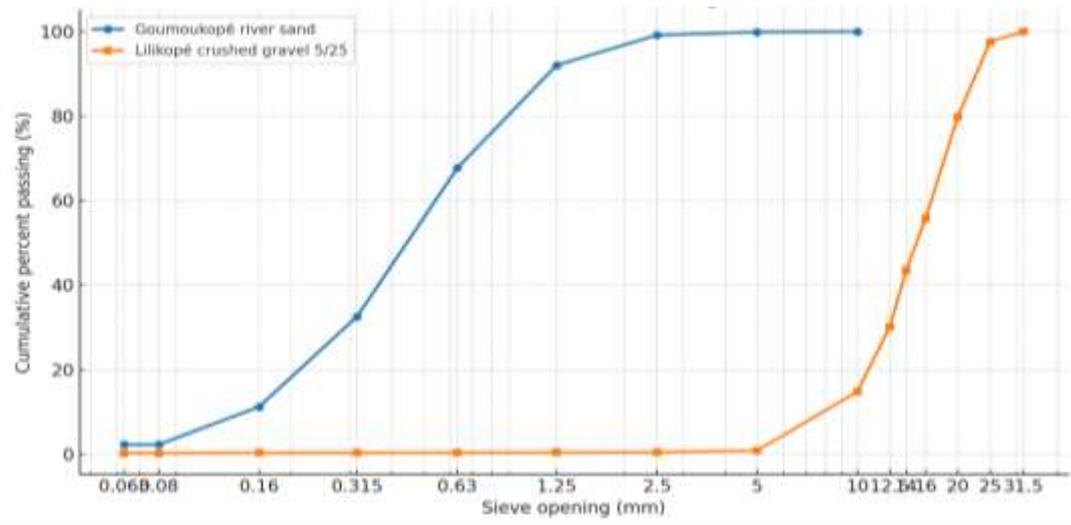


Figure 1: Particle size distribution curves of sand and gravel

The polyethylene terephthalate (PET) fibers used in this study were sourced from post-consumer plastic water bottles collected from households. After collection, a visual inspection was carried out to ensure cleanliness. Bottles showing signs of contamination were washed and then air-

dried at room temperature. Manual cutting with scissors was used to produce fibers of varying dimensions (Figure 2), with widths ranging from 1 to 2 mm and lengths between 30- and 50-mm. Table 2 summarizes the physical characteristics of the PET fibers.



Figure 2: Manually cut PET fibers

Table 2: Physical properties of plastic waste

Property	Value
Length (mm)	30–50
Width (mm)	1–2
Absolute density (g/cm ³)	1.25
Bulk density (g/cm ³)	0.08

II.2. Mix Design and Specimen Preparation

The control concrete mix, designed according to the Dreux–Gorisse method without the addition of plastic fibers, was considered as the reference formulation for

optimizing the properties of the fiber-reinforced mixes. The results from this reference mix served as the baseline for the PET fiber concretes.

The water-to-cement ratio (W/C) was kept constant at 0.55 for all aggregate compositions. The water and cement

contents used in the fiber-reinforced concretes were those determined from the Dreux–Gorisse formulation, namely 192.5 L of water and 350 kg/m³ of cement. The fiber-reinforced concrete mixes were prepared by volumetrically replacing sand with PET fibers, at replacement levels ranging from 1% to 3%, in increments of 0.5% (i.e., 1.0%, 1.5%, 2.0%, 2.5%, and 3.0%). The 0% case (no fibers) corresponded to the control concrete. These different formulations were designed to assess the effect of fiber content and geometry on the physico-mechanical properties of the concrete.

The laboratory preparation of PET fiber-reinforced concrete was carried out in compliance with the requirements of NF EN 206/CN. Fresh concrete was placed in standardized cylindrical steel molds (16 cm × 32 cm) in successive layers. Each layer was carefully compacted using a handheld electric vibrating needle. The specimens were left in the molds for 24 hours under

controlled environmental conditions before demolding.

After demolding, the concrete specimens were stored either in a humid curing room or immersed in water maintained at a regulated temperature of 20 ± 2 °C. These curing conditions were maintained until the scheduled testing dates to ensure optimal development of mechanical properties. For each formulation, six (06) specimens were produced for both physical and mechanical testing.

III. RESULT AND DISCUSSION

III.1. Slump Test (Abrams Cone) – NF EN 12350-2

The slump, measured using the Abrams cone, characterizes the consistency (workability) of fresh concrete—namely its fluidity and its ability to be placed and compacted. The slump test results are presented in Table 3, while Figure 3 shows the variation of slump with PET fiber content.

Table 3: Slump of concrete as a function of PET content

PET fiber content (%)	0	0.5	1	1.5	2	2.5	3
Slump (cm)	6	6	4	4	3.5	3.5	3

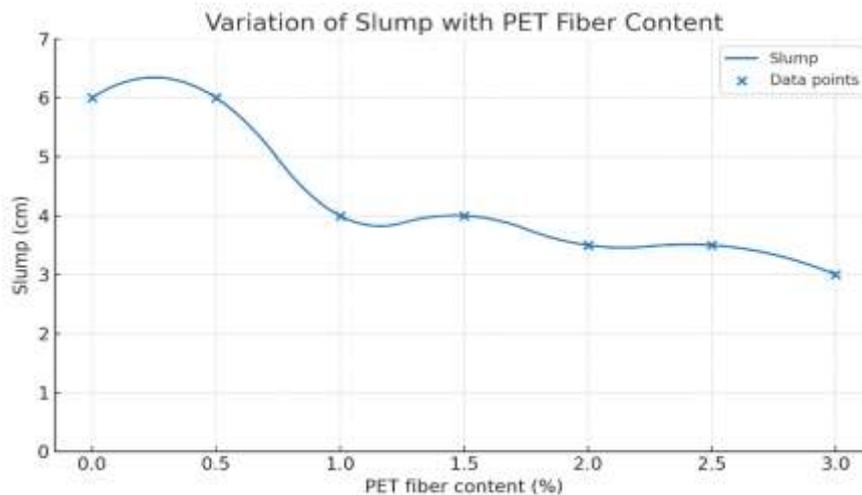


Figure 3: Variation of slump with PET content

Slump test results (NF EN 12350-2) indicate that the introduction of PET fibers progressively reduces workability from 1% replacement onwards. Both the control concrete and the mix with 0.5% PET fibers exhibited a slump of 6 cm. Increasing the

content to 1–1.5% caused a sharp drop to 4 cm (–33%). A new plateau was observed at 2–2.5% with a slump of 3.5 cm (–42%), followed by a further decrease to 3 cm at 3% PET (–50%). This trend can be explained by the increase in specific surface

area and fiber–aggregate contact, the interlocking of the 30–50 mm fibers which increases internal friction, and the partial immobilization of free water as the paste coats the fibers (PET having very low water absorption).

Practically, at a constant W/C ratio, placement becomes more demanding from 1% fiber content, requiring careful vibration. To maintain workability comparable to the control concrete, it is recommended to adjust the dosage of superplasticizer (PCE type), optimize the mixing sequence to improve fiber dispersion, and/or slightly increase the paste volume or fines content without raising the W/C ratio.

The observed slump values, ranging from 6 cm (0% PET) to 3 cm (3% PET), are consistent with recent literature: several studies report that incorporating PET (either

fibers or bottle-derived PET replacing sand) reduces workability as the content increases, sometimes with significant slump reductions. Dawood et al. (2021) reported a marked decrease in slump when sand was partially replaced with PET waste [6], while Kangavar et al. (2022) also observed a notable loss of workability [7].

III.2. Density

Density, measured in both the fresh (NF EN 12350-6) and hardened (NF EN 12390-7) states, is a key indicator of the compactness and homogeneity of concrete. The following results (Table 4) make it possible to assess the impact of varying PET fiber content on density evolution, as illustrated in the graph of Figure 4. These findings help identify the combinations that promote optimal compactness.

Table 4: Density of fresh and hardened concrete

PET content (%)		0	0.5	1	1.5	2	2.5	3
Average bulk density (g/cm ³)	Fresh concrete	2.393	2.367	2.356	2.353	2.311	2.279	2.246
	Hardened concrete	2.491	2.453	2.435	2.408	2.372	2.336	2.273

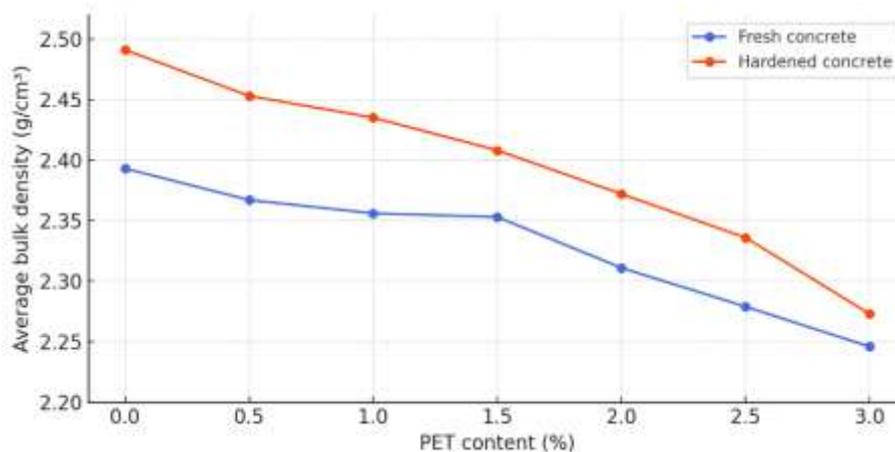


Figure 4: Variation of density with PET content

The results show an almost linear decrease in density with increasing PET content, both in the fresh and hardened states. Between 0% and 3% PET, density decreases from 2.393 to 2.246 g/cm³, which corresponds to a reduction of 0.147 g/cm³ (–6.1%) for fresh concrete, and from 2.491 to 2.273 g/cm³, a reduction of 0.218 g/cm³ (–8.8%) for hardened concrete. In terms of magnitude,

this is approximately a loss of 0.05 g/cm³ per 1% PET in the fresh state and 0.07 g/cm³ per 1% PET in the hardened state. Hardened concrete density remains higher than fresh concrete density for each PET content, but the gap narrows as PET content increases - from about +0.098 g/cm³ for the control mix to about +0.027 g/cm³ at 3% -

indicating that achieving final compactness becomes more difficult.

This trend can be explained by:

- the replacement of dense mineral sand with a lighter polymer (PET),
- the increase in internal friction and entrapped air associated with long fibers (30–50 mm), which reduce compactness, and
- the persistence of voids after hardening.

Overall, fiber-reinforced concrete becomes moderately lighter as PET content increases. To minimize the reduction in density, it is advisable to optimize fiber dispersion and vibration, use a polycarboxylate ether (PCE) superplasticizer, and/or adjust the paste or fines content without increasing the W/C ratio.

Tayeh et al. (2021) reported a reduction in both fresh and dry densities when sand was replaced by plastic (PET/PE), consistent with the simultaneous decrease observed here in fresh and hardened concrete [8]. Uche et al. (2023) also found that both fresh and dry densities decreased with increasing

PET aggregate content, with reductions of approximately –9% (fresh) and –8.8% (dry) at only 8% PET [9]. In the work of Chong and Shi (2023), the low density of PET ($\approx 1.25\text{--}1.50$; $\sim 1225\text{--}1340 \text{ kg/m}^3$) is documented, which mechanically explains the decrease in concrete density when PET replaces part of the denser aggregates [10].

III.3. Water absorption – ASTM C642

Water absorption is a key indicator of open porosity and, consequently, of the permeability and durability of cementitious materials. It reflects the ability of the capillary network to allow water to penetrate under the action of capillary forces, directly influencing resistance to aggressive agents and the long-term ageing of the material. The analysis of the results presented below (Table 5) aims to assess the effect of PET fiber content on the evolution of the water absorption coefficient over time.

Table 5: Water absorption coefficient as a function of immersion time

PET content (%)	Immersion time								
	0 h	24 h	48 h	72 h	96 h	120 h	144 h	168 h	192 h
0	0	0.11	0.14	0.19	0.27	0.32	0.34	0.34	0.34
0.5	0	0.14	0.3	0.37	0.81	0.85	0.86	0.86	0.86
1	0	0.86	1.21	2.56	3.23	3.29	3.31	3.31	3.31
1.5	0	0.06	0.1	0.16	0.19	0.2	0.25	0.25	0.25
2	0	0.07	0.31	2.3	2.56	2.61	2.66	2.66	2.66
2.5	0	0.23	2.48	2.54	7.67	7.69	7.77	7.77	7.77
3	0	0.33	6.31	6.35	6.42	6.49	6.53	6.53	6.53

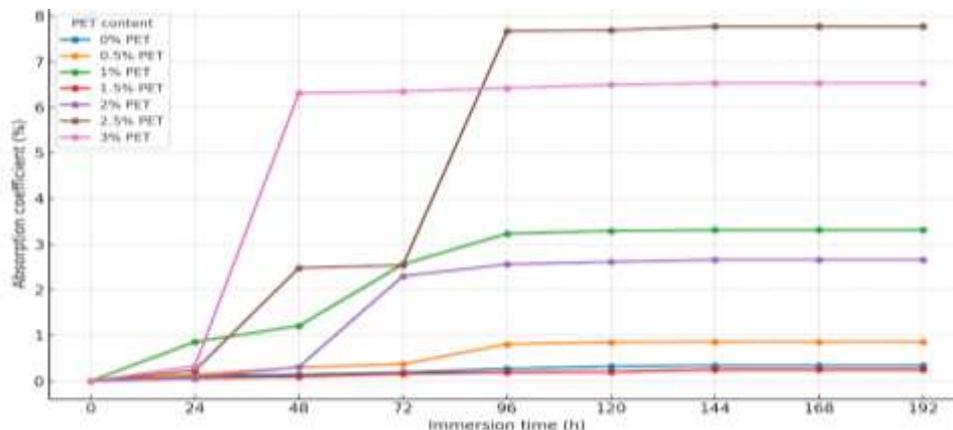


Figure 5: Evolution of the water absorption coefficient as a function of immersion time for each PET content

Water absorption increases over time and then stabilizes around 144–192 h. At 192 h, the control concrete reaches 0.34%. With 0.5% PET, it rises to 0.86% (+153%), and reaches 3.31% at 1% PET (+874%). A minimum is observed at 1.5% PET, with 0.25% (a 26% reduction compared to the control). Beyond this point, absorption increases sharply: 2.66% at 2% PET (+682%), a peak of 7.77% at 2.5% PET (+2185%), and then 6.53% at 3% PET (+1821%). This profile confirms a non-monotonic effect of PET, with an optimal zone around 1.5%.

Saturation occurs more rapidly as PET content increases—between 48–96 h for 3%, 2.5%, 2%, and 1% PET—whereas the 0% and 1.5% mixes reach their plateau later (144 h), which is consistent with a lower connected porosity at 1.5%.

Replacing dense sand with a lighter, smoother polymer increases the interfacial transition zone (ITZ) and capillary connectivity at higher dosages. Long fibers (30–50 mm) can also promote entrapped air if placement is inadequate. At 1.5%, the fiber network appears sufficiently dense to disrupt capillary continuity without generating excessive voids, resulting in the lowest absorption.

Based on this analysis, limiting absorption requires targeting 1.5% PET. Above 2%, compensation measures should include improved dispersion (optimized mixing

sequence), thorough vibration, and adjustment with a polycarboxylate ether (PCE) superplasticizer and/or paste volume to reduce voids.

Fode et al. (2024) reported that at very low contents (around 0.5%), synthetic fibers (including PET) enhance resistance to water absorption by densifying the microstructure. Beyond this threshold, the effect may reverse depending on dispersion quality and compactness [11]. Uche et al. (2023) concluded that water absorption increases with PET content (used as aggregate) due to a more porous ITZ and the hydrophobic nature of the polymer [9]. This mechanism is consistent with the increases observed at 2–3% PET in the present study.

III.4. Kinetics of Water Loss – ASTM C1585

Water loss in concrete reflects the amount of water released or evaporated over time as a result of environmental conditions or internal hydration reactions. This parameter is closely related to the porosity, compactness, and dimensional stability of the material. The analysis of the following results (Table 6) aims to highlight the influence of PET fiber content on the evolution of water loss. Figure 6 shows the variation in water loss (%) as a function of drying duration (24 to 192 h) for each PET content.

Table 6: Kinetics of water loss for each PET content

PET content (%)	Drying time							
	24 h	48 h	72 h	96 h	120 h	144 h	168 h	192 h
0	1.58	0.56	0.25	0.06	0.04	0	0	0
0.5	1.02	0.57	0.53	0.48	0.06	0	0	0
1	0.72	0.23	0.1	0.08	0.04	0	0	0
1.5	0.88	0.17	0.11	0.07	0.05	0	0	0
2	0.63	0.36	0.27	0.09	0.01	0	0	0
2.5	0.87	0.31	0.22	0.17	0.13	0	0	0
3	0.7	0.19	0.11	0.06	0.04	0	0	0

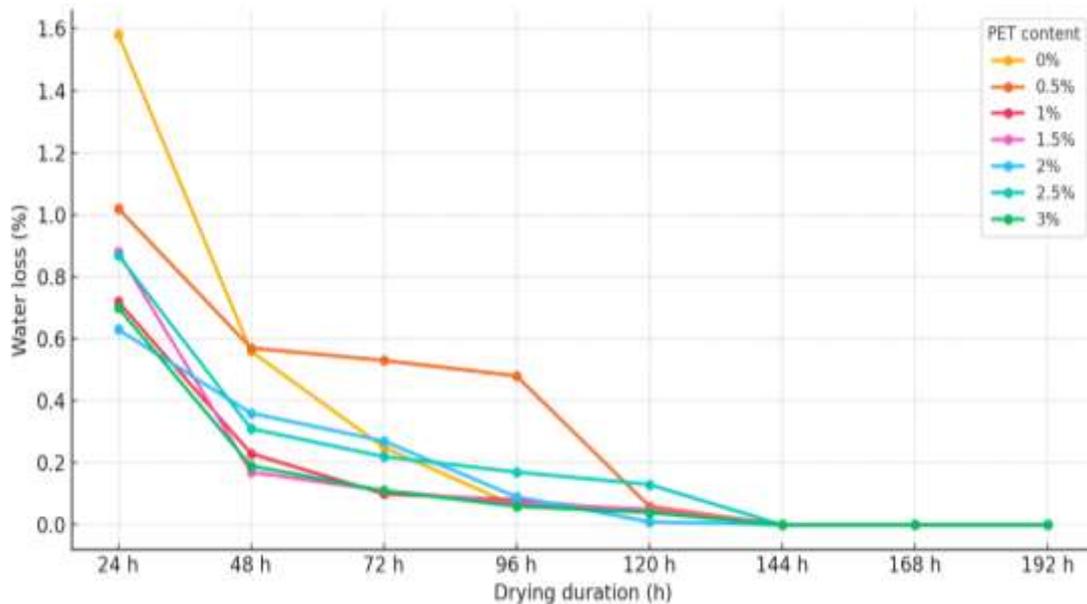


Figure 6: Evolution of water loss (%) as a function of drying duration for each PET content

Water loss decreases rapidly and becomes negligible by 144 h for all mixes. The control concrete (0% PET) releases the largest amount of water initially (1.58% at 24 h) and has already lost about 86% of its total water loss by 48 h (0.56%), indicating a high initial free water content/bleeding. At 0.5% PET, the kinetics are slower (1.02% at 24 h, then 0.53–0.48% between 72 and 96 h), with only 60% of the total water loss occurring before 48 h. The 1% and 1.5% mixes show moderate values throughout the test period (0.72 to 0.04% for 1% PET and 0.88 to 0.05% for 1.5% PET from 24 to 120 h), with 82% of the total water loss occurring before 48 h. The 2% mix is intermediate (0.63 to 0.01% from 24 to 120 h). At 2.5% PET, the terminal phase is the most persistent (0.17% at 96 h, then 0.13% at 120 h), requiring approximately 120 h to reach 95% of the cumulative loss. Finally, the 3% PET mix shows low values as early as 48–96 h (0.19 to 0.04%) and records the smallest cumulative loss overall.

Over the cumulative period (24–120 h), the highest total water loss is observed for PET contents of 0.5% and 0%, with values of 2.66% and 2.49%, respectively. The lowest are recorded for PET contents of 3%, 1%, and 1.5%, with values of 1.10%, 1.17%, and 1.28%, respectively. In other words, a low

fiber content (1–1.5%) appears to disrupt capillary continuity and limit rapid losses, while 2.5% prolongs the drying tail (slower retention and drainage). The 48–96 h period is the most critical, requiring active curing and, if necessary, improved fiber dispersion, adjustment with a PCE superplasticizer, and thorough vibration to control both the rate and magnitude of water loss.

The water loss curves from this study, showing a rapid drop between 24 and 96 h followed by near-stabilization at 144–192 h, align with the two-stage moisture transport pattern recently described for cementitious materials (an initial rapid phase followed by a slower/diffusive regime) by Zhang and Angst (2024) [12]. As PET content increases, connected porosity and water absorption increase, while adequate curing mitigates these effects; such behaviors are supported by Chong and Shi (2023) [10] and confirmed by Uche et al. (2023) [9]. Conversely, Fode et al. (2024) reported that moderate proportions of synthetic fibers ($\approx 0.5\%$) can reduce water absorption by densifying the microstructure, which is consistent with the more limited water loss observed at lower PET contents in the present study [11]. The 48–96 h window identified as critical for curing is in agreement with recent findings: Liu et al.

(2024) reported that early-age drying impairs material properties, whereas sealed or moist curing reduces water loss and its consequences [13].

III.5. Compressive strength – NF EN 12390-3

Compressive strength is one of the fundamental indicators of the mechanical performance of cementitious materials. It

reflects the ability of concrete to withstand axial loads without failure and depends directly on the quality of the matrix, compactness, and the bond within the interfacial transition zone (ITZ). The results presented in Table 7 and illustrated by the curves in Figure 7 make it possible to assess the effect of PET fiber content on the evolution of compressive strength at different curing ages.

Table 7: Compressive strength at 7 and 28 days

Age	PET content (%)	Compressive strength (MPa)	Standard deviation	Coefficient of variation (CV)
7 days	0	9.04	0.31	3.32
	0.5	11.66	0.35	2.96
	1	15.08	0.18	1.16
	1.5	16.32	0.24	1.45
	2	18.26	0.24	1.30
	2.5	14.15	0.35	2.45
	3	11.76	0.54	4.43
28 days	0	16.36	0.30	1.79
	0.5	18.68	0.87	4.48
	1	22.86	0.35	1.51
	1.5	24.79	0.31	1.23
	2	27.19	0.31	1.14
	2.5	21.72	0.42	1.93
	3	19.98	0.16	0.78

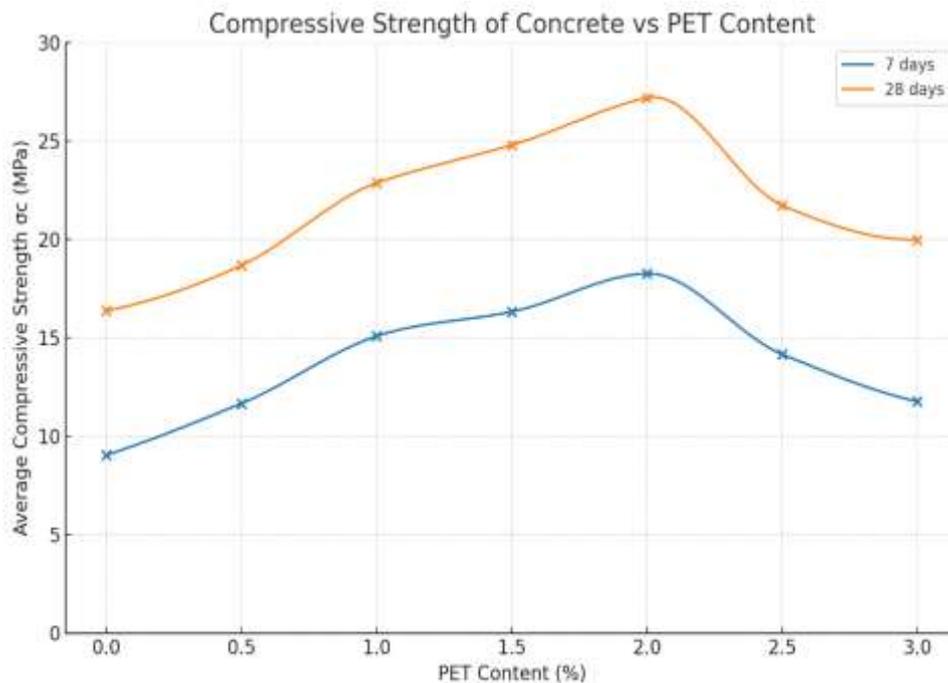


Figure 7: Evolution of compressive strength at 7 and 28 days as a function of PET content

Compressive strength increases up to around 2% PET (18.26 MPa at 7 days and 27.19 MPa at 28 days), where it reaches its maximum, and then decreases for PET contents between 2.5% and 3%. This non-monotonic behavior results from a balance between, on the one hand, the reinforcing effect of fibers (crack bridging/deflection, local confinement) which increases strength up to ~2%, and, on the other hand, the penalties related to workability and microstructure (loss of workability, entrapped air, more heterogeneous ITZ) which dominate beyond this threshold.

Slump decreases from 6 cm at 0–0.5% PET to 4 cm at 1–1.5%, then to 3.5 cm at 2–2.5%, and finally to 3 cm at 3%. Up to 2%, workability remains sufficient (with vibration) to ensure good compactness and allow fibers to perform their reinforcing role, thus increasing strength. Beyond 2.5%, low workability makes placement more difficult, increases entrapped air, and reduces compactness, leading to a decrease in compressive strength.

Although density decreases almost linearly with PET content ($\approx -6\%$ in the fresh state and $\approx -9\%$ in the hardened state between 0 and 3%), maximum strength is achieved around 2%. Up to this threshold, the structural effect of fibers compensates for the slight density loss. Beyond 2.5–3%, the density reduction (reflecting lower compactness) adds to placement difficulties, resulting in lower compressive strength.

The water absorption coefficient shows a marked minimum at 1.5% PET (~0.25%) and very high values at 2.5% and 3% (~7.8% and 6.5%, respectively). This indicates minimal connected porosity at 1.5%, whereas the optimum compressive strength occurs at 2%. In other words, absorption and strength do not vary in a strictly correlated manner. At 2%, microcrack bridging and fiber anchoring are still sufficient to enhance compressive strength despite non-minimal porosity. Beyond this point, the loss of compactness and ITZ degradation dominate, increasing

absorption and reducing compressive strength.

Water loss becomes negligible at around 144 h for all mixes, but kinetics differ. At 2.5% PET, the residual phase is the longest (0.13% still at 120 h), indicating insufficient compactness or microstructural continuity. This is consistent with the high absorption values and reduced compressive strength at this PET content. Conversely, at 1–1.5%, losses remain moderate and stabilization occurs earlier, reflecting lower capillary connectivity.

To maximize strength, 2% PET should be used with careful vibration. To improve durability and limit permeability, 1.5% PET is preferable; if needed, slightly increase the paste/fines content and adjust with a PCE-type superplasticizer to maintain workability. PET contents of 2.5–3% should only be considered with a reformulated mix design and adapted processing (PCE dosage, fiber introduction sequence, vibration), otherwise the risk of residual air increases, density decreases, absorption rises, and strength deteriorates.

In summary, the optimum for compressive strength is around 2%, while the optimum for water-related performance is around 1.5%. Beyond these levels, loss of workability and reduced compactness or ITZ quality simultaneously degrade density, absorption, and compressive strength.

For PET fiber-reinforced concrete, recent literature highlights a low-to-moderate optimal range. For contents around 0.5–2.0% by volume (20–30 mm fibers), mechanical properties are maintained or slightly improved up to ~1–2%, with microcrack bridging/deflection effects prevailing. Beyond this, strength gradually decreases due to reduced workability, less homogeneous dispersion, and entrapped air that compromise matrix compactness (Özaşık & Eren, 2022) [5]. Mohammed et al. (2023), working with PET fibers of 20–40 mm, reported an increase in compressive strength at 1% PET (8% improvement for 20 mm fibers and 6% for 40 mm fibers), followed by a decrease with higher contents,

justifying an optimum at low-to-moderate levels, in line with the peak at ~2% and drop at 2.5–3% observed in this study [14]. Similarly, Mohammed and Karim (2023), studying high-strength concrete with PET fibers, reported a reduction in compressive strength with increasing dosage (recommended ≤ 1.5% vol.), linked to decreased slump, more difficult dispersion, and entrapped air [15]. This same mechanism explains the loss of compressive strength at 2.5–3% PET in the present work.

III.6. Splitting tensile strength – NF EN 12390-6

Splitting tensile strength is a key parameter for evaluating a concrete’s ability to withstand indirect tensile stresses, which are often responsible for the initiation and propagation of cracks. The results presented in Table 8 and illustrated by the curves in Figure 8 make it possible to assess the effect of PET fiber content on the evolution of tensile strength at different curing ages.

Table 8 – Splitting tensile strength at 7 and 28 days

Age	PET content (%)	Splitting tensile strength (MPa)	Standard deviation	Coefficient of variation (CV)
7 days	0	4.57	0.20	4.32
	0.5	5.21	0.12	2.22
	1	6.94	0.24	3.31
	1.5	5.54	0.12	2.09
	2	5.96	0.12	1.95
	2.5	5.46	0.12	2.12
	3	4.90	0.40	4.74
28 days	0	5.54	0.12	2.09
	0.5	5.81	0.20	3.42
	1	8.70	0.12	1.34
	1.5	6.21	0.12	1.87
	2	7.78	0.12	1.50
	2.5	6.06	0.20	3.28
	3	5.79	0.12	2.00

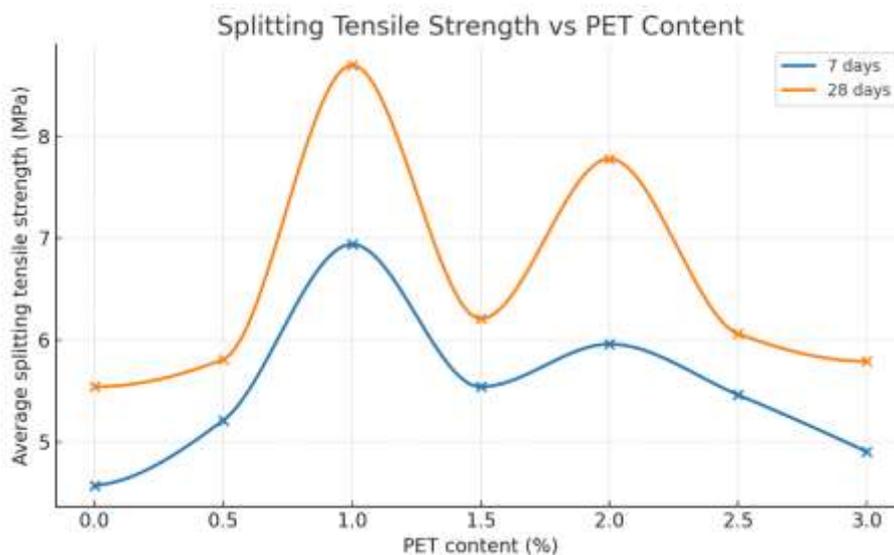


Figure 8: Evolution of splitting tensile strength at 7 and 28 days as a function of PET content

Splitting tensile strength follows a non-monotonic trend: it increases to an optimum around 1% PET, with 6.94 MPa at 7 days

and 8.70 MPa at 28 days, representing increases of 52% and 57%, respectively, compared to the control concrete. At 2%

PET, performance remains high, with 5.96 MPa at 7 days and 7.78 MPa at 28 days (increases of 30% and 40% compared to the control), although still below the maximum at 1%. Beyond this range (2.5–3%), tensile strength declines, approaching the control values. At 3% PET, only 4.90 MPa at 7 days and 5.79 MPa at 28 days are observed (+7% and +4.5%). The coefficients of variation are generally low ($CV \leq 4\%$), indicating that the measured values are highly consistent with little dispersion.

Across the 0–3% PET range, density decreases almost linearly by about 6% in the fresh state and 9% in the hardened state. The tensile strength peak appears as early as 1%, that is, before the loss of compactness becomes critical. Beyond 2%, the drop in density reflects insufficient compactness, which penalizes tensile strength first, as it is more sensitive than compressive strength to microstructural defects, particularly ITZ quality and entrapped air.

The minimum water absorption occurs at 1.5% PET (~0.25%), while splitting tensile strength reaches its maximum at 1%. This means the two indicators do not evolve in parallel. At 1%, the fiber bridging effect predominates, improving tensile strength even though porosity is not minimal. Conversely, at higher PET contents (2.5–3%), absorption increases (indicating more connected capillary porosity and a more porous paste–fiber ITZ), and tensile strength decreases.

Compressive strength reaches its maximum at around 2% PET, whereas splitting tensile strength peaks at 1%. This difference is due to tensile strength being much more sensitive to compactness defects, ITZ quality, and fiber orientation or entanglement, while compressive strength tolerates slight losses in compactness and benefits more durably from the confinement effect provided by fibers.

Between 0.5% and 1% PET, fibers disperse well and provide effective microcrack bridging, with only a limited penalty to rheology. Tensile strength then reaches its maximum, at 6.94 MPa (7 days) and 8.70

MPa (28 days) at 1% PET. Around 2%, reinforcement remains significant (5.96 MPa at 7 days, 7.78 MPa at 28 days), but the decline in workability starts to generate voids and a more heterogeneous ITZ, limiting further gains. Beyond this, at 2.5–3%, the entanglement of long fibers promotes entrapped air, increases connected porosity, and degrades paste–fiber adhesion. Tensile strength then drops significantly (from 5.46 to 4.90 MPa at 7 days and from 6.06 to 5.79 MPa at 28 days), consistent with the higher absorption and slower water loss observed at these PET contents.

To limit cracking and optimize tensile strength, a PET fiber content of about 1% should be targeted, ensuring good dispersion and thorough vibration. For a balance between tensile strength, compressive strength, and durability, the 1–1.5% range is the most relevant. In this range, tensile strength remains high, and water absorption is minimal around 1.5% PET. Conversely, PET contents of 2.5–3% should only be considered with a reformulated mix (adjusted PCE-type superplasticizer dosage, modified fiber introduction sequence, slight increase in paste/fines volume); otherwise, workability and compactness will deteriorate, absorption will increase, and strengths will decline.

The clear improvement in splitting tensile strength between 0.5% and 1–2% PET, followed by a drop at higher contents, is consistent with recent literature. Authors such as Khan (2024) and Özaşık & Eren (2022) have shown that PET fibers from bottles produce strength gains around 1% volumetric content, whereas higher contents degrade performance due to imperfect dispersion and entrapped air [5], [16].

IV. CONCLUSION

The objective of the present study is to assess the influence of polyethylene terephthalate (PET) plastic waste on the behavior of concrete, in order to evaluate the potential for using plastic waste in concrete. To this end, series of fiber-reinforced concretes with PET contents of 0,

0.5, 1, 1.5, 2, 2.5, and 3% were produced, with fiber lengths ranging from 30 to 50 mm. The various concrete specimens were subjected to tests to determine their physical and mechanical properties.

The conclusions drawn from the results of this study can be summarized as follows:

Between 0% and 3% PET, density decreases by 6% in the fresh state and 9% in the hardened state, in an almost linear manner and more markedly after hardening. This reflects greater difficulty in achieving optimal compactness as fiber content increases. The water absorption coefficient reaches a clear minimum at 1.5% fiber content, then increases sharply beyond 2%. Saturation occurs between 144 and 192 h. A low PET content (1–1.5%) disrupts capillary continuity and limits rapid losses, whereas higher contents reduce compactness and increase connected porosity.

In terms of performance, the optimum compressive strength is found at around 2% PET, while the optimum splitting tensile strength is around 1% (with a secondary peak at 2%). The optimum in terms of water performance (minimum absorption) is around 1.5%. Beyond these levels, the reduction in workability and the degradation of compactness or of the interfacial transition zone (ITZ) simultaneously deteriorate density, absorption, and strength. To control cracking and maximize compressive strength with satisfactory reproducibility, 2% PET should be used with careful fiber dispersion and thorough vibration. For a balanced compromise between tensile strength, compressive strength, and durability, contents in the range of 1–1.5% are preferable, with absorption being minimal around 1.5% PET. Above 2% PET, a controlled mix design and reinforced placement procedures are essential—including adjustment with a polycarboxylate ether (PCE) superplasticizer and a proper sequence for gradually introducing the fibers—otherwise, workability, compactness, absorption, and strengths will deteriorate simultaneously.

For the continuation of this study, a life cycle assessment and tests in aggressive environments, such as chloride solutions, will be necessary.

Declaration by Authors

Acknowledgement: The authors wish to thank the GEOTECH. Sa laboratory and its staff for facilitating the successful conduct of the various tests at their facilities.

Source of Funding: None

Conflict of Interest: No conflicts of interest declared.

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How to cite this article: Koudzo ASSAGBAVI, Kouandété Valéry DOKO, Djidoula TAKO. Effect of polyethylene terephthalate (PET) fibers on concrete properties. *International Journal of Research and Review*. 2025; 12(9): 85-98. DOI: [10.52403/ijrr.20250910](https://doi.org/10.52403/ijrr.20250910)
