ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering | e–ISSN: 2067 – 3809
Tome XIX [2026] | Fascicule 1 [January – March]

[1.] Solomon I. ADEDOKUN, [1.] Funmilola D. OGUNREMI, [1.] Yetunde O. ABIODUN, [2] Samuel A. AYANLERE

EFFECT OF POLYETHYLENE TEREPHTHALATE (PET) AND NEXUS 85 MACRO SYNTHETIC FIBRES ON THE PROPERTIES OF CONCRETE

[1.]Department of Civil and Environmental Engineering, University of Lagos, NIGERIA
[2.]Department of Civil Engineering, LAUTECH, Ogbomoso, NIGERIA

Abstract: This research studied the effect of PET fibres and Nexus 85 macro synthetic fibres on the performance characteristics of concrete. Although each fibres have been studied individually, limited research has focused on their combined application. The research, therefore, assessed the influence of PET and Nexus 85 fibres, used singly and in combination, on the mechanical and durability properties of concrete, with emphasis on identifying the optimal hybrid mix ratio. An experimental programme was designed using five concrete mixes: M1 (Control – 0% fibres), M2 (0.5% PET), M3 (0.5% PET + 0.5% Nexus 85), M4 (0.25% PET + 0.25% Nexus 85), and M5 (0.5% Nexus 85). Each mix was subjected to slump, compressive strength, split tensile strength, flexural strength, and water absorption tests. Results showed that PET fibres improved the workability of the concrete, while Nexus 85 fibres improved the strength and resistance to cracking. The M5 mix containing 0.5% Nexus 85 only exhibited the highest compressive and tensile strengths, while the hybrid M3 mix with 0.5% PET and 0.5% Nexus 85 achieved the greatest flexural strength. PET fibres reduced water absorption,showing improved durability. The study concludes that combining PET and Nexus 85 fibres creates a sustainable hybrid fibre reinforced concrete with good strength and durability. This hybrid system is recommended for structures that require crack control and long-lasting performance, as it supports a more environmentally friendly way to design concrete.

Keywords: Durability, Mechanical properties, Mix ratio, Nexus 85 fibre, PET fibre

INTRODUCTION

Concrete is used extensively in civil engineering projects, due to its high compressive strength, durability, and adaptability in various structural applications. Despite its many useful properties, concrete has some drawbacks in comparison to other common construction materials, concrete has relatively low tensile strength and ductility. This makes it more likely to crack. When load is placed on unreinforced concrete, tiny cracks form, merge and turn into larger cracks. With further loading, these larger cracks can lead to serious failure (Banthia *et al.*, 2014). In the past, the construction industries depended on steel reinforcements and synthetic fibres to address concrete weaknesses, such as its low tensile strength and brittleness. While steel reinforcements can significantly improve structural strength and load capacity, they also have setbacks. These include high material and installation costs, vulnerability to rust in humid or salty conditions (which can lead to long term structural damage), and the additional weight they add to buildings, which complicates transport, increases the load on foundations, and raises carbon emissions during production and transport. These shortcomings have shifted research attention towards fibre reinforced concrete (FRC), a composite material that incorporates discrete fibres to improve post-cracking behavior, ductility, and fatigue resistance. Fibres in FRC bridges rarely cracks, limit their width, and enhance stress redistribution, resulting in superior durability and serviceability (Manik *et al.*, 2022).

In parallel, the global escalation of plastic waste particularly from polyethylene terephthalate (PET) bottles has become an urgent environmental concern. PET bottles constitute roughly 30% of global plastic waste (Geyer *et al.*, 2017). Converting waste PET into construction materials offers a promising dual benefit, reducing environmental pollution while producing cost-effective and sustainable building composites. PET fibres have been used successfully to improve the toughness and crack resistance of cementitious materials, while nations such as India have demonstrated the viability of large-scale PET recycling in infrastructure projects (Indian Roads Congress, 2021). Recent advancements in macro synthetic fibres, such as Nexus 85 have further expanded the possibilities for sustainable fibre reinforced concrete. Nexus 85 fibres, unlike steel, are non-corrosive, lightweight, and chemically inert, offering improved crack control and durability even in aggressive environments (Zollo, 1997). However, while PET and macro synthetic fibres have been individually studied, research integrating these two fibres into hybrid systems remains scarce. Hybridization has the potential to combine the toughness and crack-bridging capacity of synthetic fibres with the environmental and economic benefits of recycled PET. Yet, few studies have explored the mechanical and durability behavior of concrete reinforced with hybrid PET and Nexus 85 fibres under realistic, additive-free conditions. Particularly, limited data exists on how such hybrids influence key durability parameters such as water absorption and long-term performance. This study therefore addresses this critical research gap by experimentally investigating the combined effects of PET fibres and Nexus 85 macro synthetic fibres on the mechanical and durability properties of concrete, using practical fibre dosages (0.25% and 0.50%) and standardized testing methods. The outcomes will contribute valuable insights into the development of sustainable, high performance hybrid fibre reinforced concrete and provide practical guidance for its implementation in structural applications.

MATERIALS AND METHODS

Materials

Ordinary Portland Cement (OPC) of grade 42.5N produced in Nigeria was used for the experiment. Natural river sand with particle size ≤4.75 mm was locally sourced while the crushed granite with a maximum size of 20 mm was used. Clean Potable water collected from local borehole was utilized in mixing the other concrete constituents together.

(a)

(b)

Figure 1: Pictorial views of: (a) Polyethylene terephthalate fibre, (b) Nexus 85 fibre

The polyethylene terephthalate (PET) fibres (Figure 1a) was obtained from waste PET bottles, it was shredded and grounded into irregular fibres with sizes approximately ranging from 10mm-50mm, while the Nexus 85 fibre (Figure 1b), containing 60 mm length, 0.7 mm nominal diameter and the aspect ratio of 86, was procured commercially. The Polypropylene fibres were used in present study which was procured from Jila Engineering limited, Lagos.

Experimental methods

Specimen preparation

This research used a mix ratio of 1:2:4 for cement, fine aggregate, and coarse aggregate, respectively, with a water-cement (W/C) ratio of 0.5. Table 2 shows the experimental combinations of the two fibres.

Table 2: Compositions of the PET and Nexus 85 fibres used

Mix	Mix Constituents
M1	Control mix
M2	0.5% PET fibre
M3	0.5% PET + 0.5% Nexus 85 fibre
M4	0.25% PET + 0.25% Nexus 85 fibre
M5	0.5% Nexus 85 fibre

Slump

Workability of the concrete containing different fibre combinations (Table 2) was determined using the standard slump cone test in accordance with BS EN 12350-2 (2009). The cone measured 300 mm in height, with bottom and top diameters of 200 mm and 100 mm, respectively. The tamping rod was made of steel, 16 mm in diameter, 600 mm long, and rounded at one end. Before testing, the cone was cleaned and set on a smooth, firm, non-absorbent base to get accurate results. The cone was filled with concrete in four equal layers, and each layer was tamped 25 times with the rounded end of the rod. After filling, extra concrete was removed, and the top was leveled with a trowel. The cone was lifted straight up, and the drop in concrete height was recorded as the slump value. This value showed how workable each mix was and made it possible to compare different types of concrete.

Compressive strength

This property was measured with a Universal Testing Machine at the structure and materials Laboratory of the University of Lagos, Lagos, Nigeria. For compressive strength test, three cube specimens (150 x 150 x 150 mm) were prepared for each concrete combination: plain concrete, PET fibre reinforced concrete, Nexus 85 fibre-reinforced concrete, and PET with Nexus 85 fibre-reinforced concrete in varying percentages. Tests were conducted at 7, 14, and 28 curing days following the standard procedures outlined in the BS EN 12390-3 (BSI, 2002). The specimens were removed from water, surface-dried, weighed and placed centrally on the machine platen. The load was applied continuously and uniformly until failure. The highest load each specimen could bear was recorded. Compressive strength was then calculated by dividing this load by the specimen's cross-sectional area.

— **Split tensile**

Split tensile strength of concrete was measured using the Brazilian test method in accordance with ASTM C496 (2017). For the split tensile strength tests, three standard cylindrical specimens, each 150 mm in diameter and 300 mm in height, were prepared for all the mixes, cured for 7 and 28 days and tested after the required curing periods. On the test day, the cylinders were removed from the curing tank, surface moisture was wiped off, and their dimensions were measured. Each specimen was positioned horizontally between the plates of a calibrated compression testing machine. Two plywood strips, 3 mm thick and 25 mm wide, were placed along the top and bottom of the cylinder to ensure a uniform line of contact and to distribute the load evenly. The load was applied continuously and smoothly at a controlled rate, typically between 1.2 and 2.4 MPa per minute, until the specimen split along its vertical diameter. The maximum load at failure was recorded, and the splitting tensile strength was calculated.

— **Flexural strength**

Flexural strength testing was conducted using beam specimens with dimensions of 150 mm by 150 mm by 750 mm. Three specimens were tested for each category and cured for 7 and 28 days. All procedures adhered to BS EN12390-5 (BSI, 2000). To minimize strength loss due to surface drying, specimens were tested immediately after removal from moist storage. The load was applied gradually to avoid sudden force. The third-point loading method ensured uniform force distribution across the beam. Following placement, a single concentrated load was applied at the mid-span using a hydraulic jack with controlled pumping. The maximum load sustained by

— **Water absorption**

Water absorption test was carried out on the concrete specimens accordance with ASTM C642 (2013) after 28 days of water curing to evaluate the degree of porosity and the potential durability of the mixes. Specimens were weighed immediately after removal from the curing tank, and these values were compared with their corresponding dry weights to determine percentage absorption.

RESULTS AND DISCUSSION

▦ Workability

Figure 2 shows the effect of the varying combinations of the PET and Nexus 85 fibres on the workability of concrete. The slump results presented in the Figure indicates significant variations in workability due to the addition of these fibres.

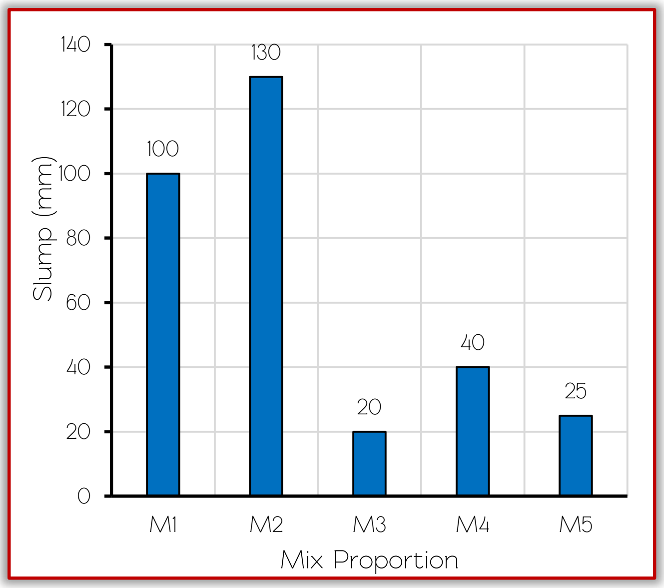

Figure 2: Effect of fibre combinations on slump value

The control mix (M1) had a 100 mm slump, while the 0.5% PET mix (M2) achieved the highest value of 130 mm, showing that PET fibres improved workability through their smooth, water-repellent surfaces that reduce friction among aggregates. Conversely, Nexus 85 fibres significantly lowered slump values, 25 mm for the Nexus only mix (M5), 20 mm for M3, and 40 mm for M4, due to their rough, interlocking texture, which increased water demand and limited flow. These aligns with the findings of Kim *et al.* (2010) and Foti (2013), who reported that PET fibres improve workability when used in small proportions. In contrast, Saikia and de Brito (2014) and Choi *et al.* (2005) found that irregular or shredded PET forms may reduce workability by increasing surface area and water demand. The improvement observed in this study may therefore be attributed to the uniform fibre geometry and proper mixing sequence, which helped prevent fibre balling and segregation. However, higher hybrid contents (M3 and M4) led to reduction in slump compared to M2. Mohd *et al.* (2021) and Johnston (2010) also observed that this may be caused by the fibre interlocking restricting paste flow. Overall, the study shows that using PET fibres at a 0.5% dosage improves workability, but hybridization needs to be handled and managed carefully to keep the mix consistent.

▦ Compressive strength

The effect of varying fibre combinations on the compressive strength of concrete at 7, 14 and 28 curing days is presented in Figure 3. The control mix (M1) achieved the compressive strengths of 12.40, 16.18, and 16.74 N/mm² at 7, 14, and 28 days, respectively, showing a 35% gain of normal hydration progression at 28th day. The PET mix (M2) recorded 8.77, 11.41, and 12.19 N/mm², with a 38.96% gain but 27% lower strength than the control, due to PET's smooth, hydrophobic surface and weak bond with the matrix. The hybrid mix of 0.5% PET + 0.5% Nexus (M3) showed the best performance among the hybrids, reaching 13.12, 16.60, and 17.95 N/mm², with 7% above the control and 47% higher than M2 (PET only). The synergy of PET and Nexus improved crack bridging and stress transfer. The lower hybrid mix (M4) achieved 9.71, 12.65, and 13.31 N/mm², with 20% lower than the control, indicating insufficient fibre content for reinforcement. The Nexus only mix (M5) gave the highest strengths, 14.52, 17.17, and 19.74 N/mm² at 7, 14 and 28 days, with an 18% improvement over the control. Its superior performance stems from strong mechanical anchorage and efficient crack control.

This result is consistent with Afroughsabet *et al.*, (2016), who found that macro synthetic fibres can significantly improve the post-cracking strength of concrete. Yoo and Banthia (2017) also showed that synthetic fibres slow down crack formation and boost compressive performance when concrete is confined. In this research, the improvement likely came from the fibres bridging small cracks and spreading out stresses as the concrete is loaded. Some studies, such as Ragavendra *et al.* (2017), found only small gains in compressive strength with the addition of fibres. These differences are often linked to the shape, length, or bonding of the fibres. In this research, the even spread and stiffness of the Nexus 85 fibres seem to have played a key role in increasing the concrete strength.

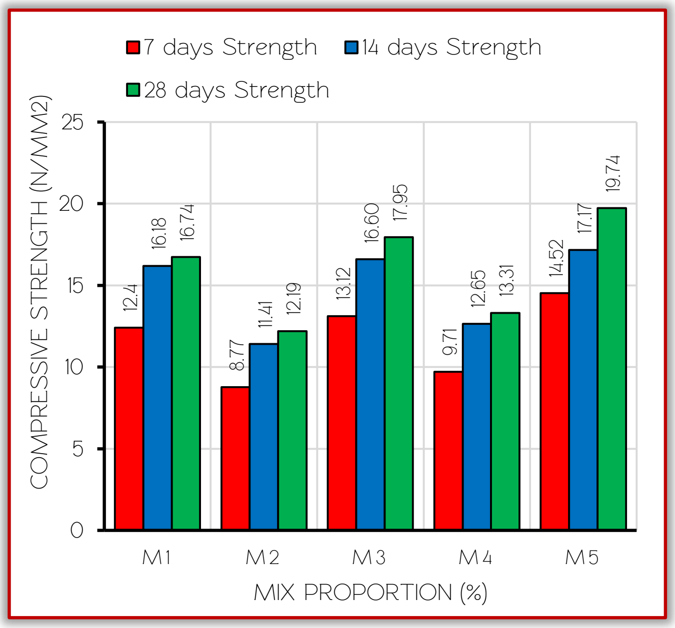

Figure 3: Effect of fibre combinations of the compressive strength of concrete

Split tensile strength

Figure 4 shows the effect of varying fibre combinations of the tensile strength of the concrete at 7 and 28 days. The control mix (M1) attained the tensile strengths of 7.47 N/mm² and 8.32 N/mm² at 7 and 28 days, showing typical hydration-based gains. The PET mix (M2) improved slightly to 7.73 N/mm² and 8.60 N/mm², while the 0.25% PET + 0.25% Nexus hybrid (M4) reached 7.87 N/mm² and 8.83 N/mm², indicating slight increase in strength and limited crack control at low fibre dosages. However, greater improvements were seen with higher fibre contents. The 0.5% PET + 0.5% Nexus hybrid (M3) achieved 9.47 N/mm² and 10.12 N/mm², representing a 21.6% improvement compared to the control mix, suggesting an effective synergy between PET and Nexus fibres. The Nexus only mix (M5) had the best performance, reaching 9.67 N/mm² and 11.65 N/mm², with a 40% increase in comparison to the control mix, demonstrating the superior crack-bridging and stress transfer capacity of Nexus fibres.

In summary, all mixes gained strength with age due to ongoing hydration. PET provided modest improvements, while Nexus fibres, alone or in hybrid form, significantly enhanced tensile performance. This outcome supports the findings of Minelli and Plizzari (2017), who reported that fibre inclusion improves tensile capacity by preventing crack coalescence and by increasing post-peak ductility. Banthia and Gupta (2006) also noted that synthetic fibres enhance plastic shrinkage resistance and delay crack widening under tensile stress. On the other hand, PET fibres alone (M2) produced only a moderate increase in tensile strength. This aligns with Foti (2013) and Saikia and de Brito (2014), who observed that PET fibres improve tensile strain capacity but may not substantially increase the peak tensile strength. The hybrid mixes (M3 and M4) demonstrated slightly lower tensile strength than M5 but still exceeded the control, suggesting a combined reinforcement mechanism that enhances ductility rather than ultimate strength. The results show variations in performance depending on fibre type and dosage.

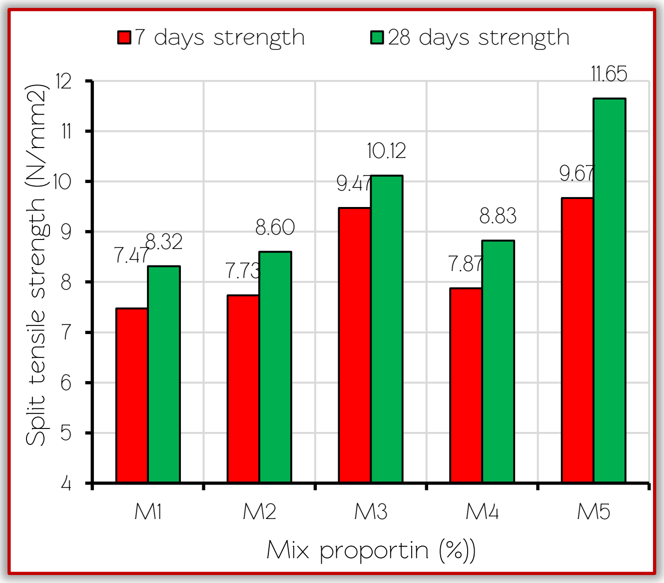

Figure 4: Effect of fibre combinations on the split tensile strength of concrete

▦ Flexural strength

Figure 5 present the effect of varying fibre combinations on the flexural strength of concrete after the 7 and 28 curing days. All mixes showed progressive flexural strength gains from 7 to 28 days due to continued hydration and fibre reinforcement. The control mix (M1) increased from 8.30 N/mm² to 9.19 N/mm², remaining brittle with wide cracks. The PET only mix (M2) improved to 10.07 N/mm², with reduced crack widths (5.3 to 4.2 mm), showing modest ductility gains. The hybrid mix (M3) performed best, rising from 10.37 to 11.85 N/mm² and recording the smallest cracks (2.7 to 2.4 mm). The PET addition to concrete controlled microcracks, while Nexus fibres bridged larger ones, giving superior toughness. The balanced hybrid (M4) reached 10.37 N/mm², with moderate crack reduction, indicating limited synergy at lower fibre content. The Nexus-only mix (M5) achieved 11.26 N/mm² and maintained narrow cracks (2.5 to 2.4 mm), confirming strong crack control and ductile failure. These results align with Banthia & Nandakumar (2003), Fraternali *et al.* (2011), and Afroughsabet *et al.* (2016), who found that hybrid fibres enhance toughness and flexural strength through multiple crack-bridging mechanisms. Overall, proper fibre combination and dispersion improved stress transfer and significantly boosted flexural performance.

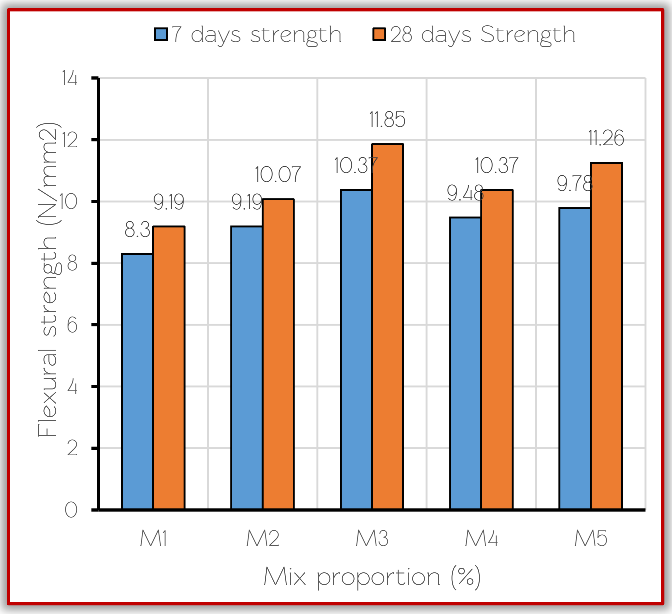

Figure 5: Effect of fibre combinations on flexural strengths of concrete

▦ Crack pattern observation

The crack patterns observed from the flexural test, which illustrate the effect of fibre reinforcement on crack control, are presented in Figure 6. After 7 days of curing, the control mix (M1) showed wide, irregular cracks (6 mm to10 mm), confirming its brittle nature. The PET mix (M2) displayed narrower cracks (4 mm to 7 mm), showing limited bridging, while the Nexus-only (M5) and hybrid (M3) mixes had the smallest, most uniform cracks (2mm to 3 mm), indicating effective stress distribution and crack restraint. By 28 days, all mixes exhibited finer cracks due to continued hydration and stronger fibre bonding. The control still showed wide cracks (5.5 mm to 7 mm), while PET (M2) reduced them to 3.5mm to 5 mm. The hybrid (M3) had the narrowest, most uniform cracks (1.8 mm to 3 mm), and the Nexus-only mix (M5) achieved similar widths with slightly less uniformity. The low-dosage hybrid (M4) recorded 3 mm to 4.4 mm cracks, reflecting reduced effectiveness. These findings agree with Fraternali *et al.* (2011), who reported that hybrid fibres yield finer, evenly spaced cracks, and contrast slightly with Ragavendra *et al.* (2017), who observed limited improvement with single synthetic fibres.

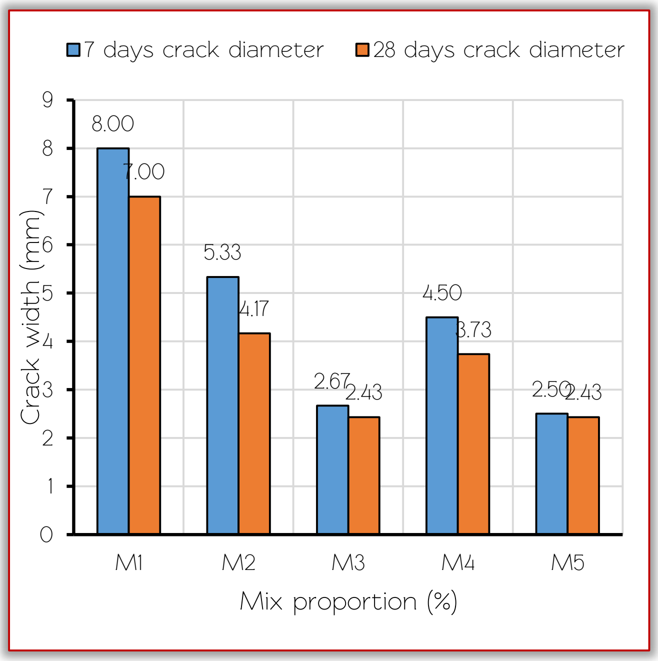

Figure 6: Effect of fibre combinations on crack pattern of the concrete beams

Failure mode of the control beam (A)

Failure mode of fibre reinforced beam (B)

Figure 7: Failure modes of the control and fibre reinforced beams

In summary, the control beam (Figure 7a) failed abruptly in a brittle manner, splitting into two parts, while fibre-reinforced beams (Figure 7b) developed controlled cracks but remained intact. This shows that fibres enhanced ductility, allowing better stress transfer and preventing sudden failure. Overall, incorporating PET and Nexus 85 fibres, especially in combination, transformed the failure mode from brittle to ductile, delaying crack initiation and improving strength, toughness, and energy absorption capacity.

Water absorption

Figure 8 presents the effect of different fibre combinations on the water absorption of the unreinforced (control, M1) and fibre-reinforced (M2–M5) concrete specimens. Absorption values ranged from 0.47% to 1.93%, all below the 10% durability limit (ASTM C642, 2013; Neville, 2011) confirming good concrete quality and density. The control mix (M1) had a value of 0.60%, while the PET-only mix (M2) had the lowest value (0.47%), showing that PET fibres reduced pore connectivity and permeability. The hybrid mix with 0.5% PET + 0.5% Nexus (M3) recorded 0.85%, likely due to microvoids from higher fibre content. The balanced hybrid (M4) had the highest value (1.93%), possibly from uneven fibre dispersion which increased the pore linkage. The Nexus-only mix (M5) showed 1.13%, indicating that while Nexus fibres improved strength, their permeability control was less effective than PET's. These results align with Albano *et al.* (2009), Saikia and de Brito (2014), and Foti (2013), who reported that PET fibres enhance concrete's impermeability and resistance to moisture ingress.

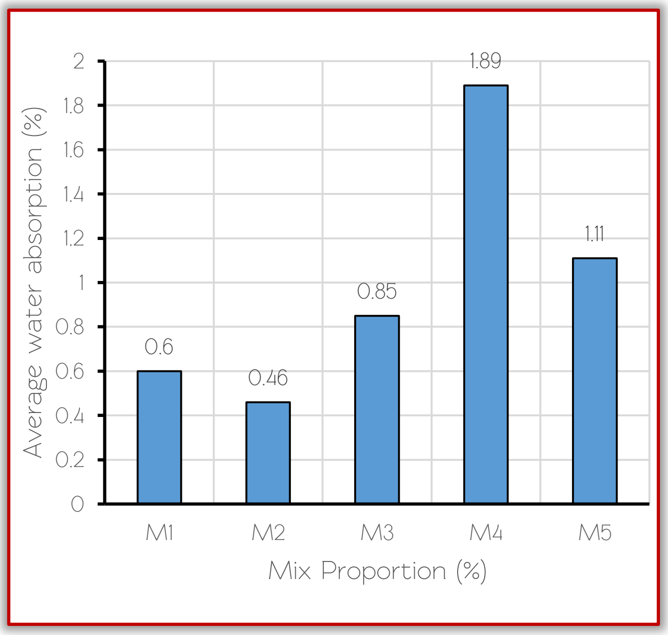

Figure 8: Effect of fibre combinations on the water absorption property of concrete

CONCLUSION

This research examined the combined effects of PET fibres and Nexus 85 macro synthetic fibers as hybrid reinforcement in concrete, a combination not previously explored in literature. While earlier studies focused on PET fibers for sustainability and Nexus 85 fibers for their structural benefits, this study stands out by evaluating their synergistic effects. Slump test results demonstrated that fibre type and dosage substantially affect concrete workability. Polyethylene terephthalate (PET) fibres increased slump and improved workability, whereas Nexus 85 fibres markedly reduced slump, resulting in stiff mixtures. Hybrid mixes containing both PET and Nexus 85 fibres exhibited the lowest slump values, with the stiffening effect of Nexus 85 predominating. These findings indicate that PET fibres enhance flowability, while Nexus 85 fibres restrict it, underscoring the necessity for precise mix design adjustments when combining fibres to ensure adequate workability.

The study shows that fibre type and dosage have a strong influence on concrete performance. PET fibres reduced compressive, tensile, and flexural strengths while increasing water absorption, despite improving workability. In contrast, Nexus fibres significantly enhanced strength, crack resistance, and durability, with 0.5% Nexus achieving the best overall results. The value obtained for 0.5% addition of Nexus 85 fibre yielded the highest results for compressive strength of 19.74N/mm^2 at 28 days outperforming the control mix by 18%. Hybridization produced mixed outcomes: the equal hybrid (0.5% PET + 0.5% Nexus) improved properties beyond the control, while the lower hybrid dosage was ineffective. Overall, Nexus fibres proved structurally superior, whereas PET fibres require hybridization at adequate dosages to be beneficial.

The value obtained for 0.5% addition of Nexus 85 fibre (M5) yielded the highest results for split tensile strength of 11.65 N/mm^2 at 28 days outperforming the control mix by 40% respectively. These results show that Nexus 85 fibers improved crack-bridging and stress distribution more than PET and the hybrid mixes. As a result, they led to the largest increase in tensile capacity compared to the control concrete. For the flexural strength, the optimum fibre dosage 0.5% PET and 0.5% Nexus 85 fibre yielded the highest strength of 11.85 N/mm^2 at 28 curing days outperforming the control mix by 28.9%, this mix also had the narrowest cracks (2.7 mm to 2.4 mm).

The hybrid mix with 0.5% PET and 0.5% Nexus (M3) performed best, exhibiting the highest strength and finest crack distribution, which confirms hybridization as the most effective approach for enhancing performance and durability.

The water absorption results confirm that all mixes produced durable concrete, with values well below the 10% threshold. PET fibres at moderate dosage (0.5%) proved most effective in reducing water absorption, while higher hybrid fibre contents increased permeability. When compared with the mechanical strength results, it can be inferred that PET fibres enhanced durability by limiting water ingress, whereas Nexus 85 fibres contributed more significantly to the improvement in strength.

REFERENCES

[1] Afroughsabet, V., Biolzi, L., and Ozbakkaloglu, T. (2016). High-performance fibre reinforced concrete: A review. Journal of Materials Science, 51, 6517–6551.

[2] Albano, C., Camacho, N., Hernández, M., Matheus, A., and Gutiérrez, A. (2009). Influence of content and particle size of waste PET bottles on concrete behavior at different w/c ratios. Waste Management, 29(10), 2707–2716.

[3] ASTM International. (2013). ASTM C642–13: Standard test method for density, absorption, and voids in hardened concrete. West Conshohocken, PA: ASTM International.

[4] ASTM International. (2017). ASTM C496/C496M–17: Standard test method for splitting tensile strength of cylindrical concrete specimens. West Conshohocken, PA: ASTM International.

[5] Banthia, N., and Gupta, R. (2006). Influence of polypropylene fibre geometry on plastic shrinkage cracking in concrete. Cement and Concrete Research, 36(7), 1263–1267.

[6] Banthia, N., and Nandakumar, N. (2003). Crack growth resistance of hybrid fibre reinforced cement composites. Cement and Concrete Composites, 25(1), 3–9.

[7] Banthia, N., Zanotti, C., and Sappakittipakorn, M. (2014). Sustainable fibre reinforced concrete for repair applications. Construction and Building Materials, 67, 405–412.

[8] British Standards Institution. (2000). Testing hardened concrete – Part 5: Flexural strength of test specimens (BS EN 12390-5:2000). London, United Kingdom: BSI.

[9] British Standards Institution. (2002). Testing hardened concrete – Part 3: Compressive strength of test specimens (BS EN 12390-3:2002). London, United Kingdom: BSI.

[10] British Standards Institution. (2009). Testing fresh concrete – Part 2: Slump test (BS EN 12350-2:2009). London, United Kingdom: BSI.

[11] Choi, Y. W., Moon, D. J., Chung, J. S., and Cho, S. K. (2005). Effects of waste PET bottles aggregate on the properties of concrete. Cement and Concrete Research, 35(4), 776–781.

[12] Foti, D. (2013). Use of recycled waste PET bottle fibres for the reinforcement of concrete. Composite Structures, 96, 396–404

[13] Fraternali, F., Ciancia, V., Chechile, R., Rizzano, G., Feo, L., and Incarnato, L. (2011). Experimental study of the thermo-mechanical properties of recycled PET fibre reinforced concrete. Composite Structures, 93(9), 2368–2374

[14] Geyer, R., Jambeck, J. R., and Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782

[15] Indian Roads Congress. (2021). Guidelines for the use of waste plastic in hot bituminous mixes (IRC: SP: 98-2021). New Delhi, India: Indian Roads Congress.

[16] Johnston, C. D. (2010). Fibre reinforced cements and concretes., 372

[17] Kim, S. B., Yi, N. H., Kim, H. Y., Kim, J. H. J., and Song, Y. C. (2010). Material and structural performance evaluation of recycled PET fibre reinforced concrete. Cement and Concrete Composites, 32(3), 232–240

[18] Manik, B., Alieu, K., and Austin, J. (2022). Establishing fresh properties of fibre reinforced concrete for performance engineered mixture (PEM). Minnesota Department of Transportation Office of Research and Innovation, (MnDOT Rep. No. 2022-23). Minnesota Department of Transportation

[19] Minelli, F., Plizzari, G. A., and Tiberti, G. (2017). Comparing test methods for the mechanical characterization of fibre reinforced concrete. Structural Concrete, 19(3), 656–669.

[20] Mohd, A. S., Abdul, R., Grace, S., and Faizan, M. (2021). Comparative study between fibre reinforced concrete (glass, jute, steel fibre) with traditional concrete. International Journal of Engineering Research and Technology, NREST 2021, 9(4), 168–171

[21] Neville, A. M. (2011). Properties of concrete (5th ed.). Harlow, England: Pearson Education Limited.

[22] Ragavendra, S., Reddy, I. P., and Archanaa, D. (2017). Fibre reinforced concrete – A case study. Veermata Jijabai Technological Institute, 3–9.

[23] Saikia, N., & de Brito, J. (2014). Mechanical properties and abrasion behaviour of concrete containing shredded PET bottle waste as a partial substitution of natural aggregate. Construction and Building Materials, 52, 236–244. https://doi.org/10.1016/j.conbuildmat.2013.11.049

[24] Yoo, D. Y., and Banthia, N. (2017). Mechanical and structural behaviors of ultra-high-performance fibre reinforced concrete subjected to impact and blast. Construction and Building Materials, 149, 416–431

[25] Zollo, R. F. (1997). Fibre reinforced concrete: An overview after 30 years of development. Cement and Concrete Composites, 19(2), 107–122

ISSN: 2067–3809