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INFLUENCE OF NYLON FIBER LENGTH ON MECHANICAL STRENGTH AND VOID CONTENT OF PERVIOUS CONCRETE

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Abstract

Pervious concrete contains a connected network of pores that allows water to pass through the material and can help limit surface runoff. This porosity, however, may also affect its load-bearing capacity. This work examined how nylon-fiber length influences compressive strength, splitting tensile strength, and measured void content when the fiber dosage is held constant. The laboratory program comprised 36 cylindrical specimens (150 mm × 300 mm) representing a plain mixture and mixtures reinforced with nylon fibers 20, 30, or 50 mm long. Fiber dosage was 0.9 kg/m³, and testing was performed at 28 days. Mean compressive strength was 19.43 MPa for the control, compared with 19.21, 18.89, and 18.65 MPa for the 20, 30, and 50 mm mixtures, respectively. These values represent reductions of 1.13%, 2.78%, and approximately 4.01%. Splitting tensile strength did not follow a monotonic trend: the respective means were 1.748, 1.746, 1.775, and 1.675 MPa. The 30 mm mixture had the largest measured mean, 1.775 MPa, around 1.54% above the control. Measured void content was 26.16% for the control and 26.32%, 37.89%, and 27.39% for the reinforced mixtures. Thus, fiber length was associated with different responses across the properties measured under the conditions of this experiment.

Keywords:
Compressive strength; Fiber length; Nylon fiber; Pervious concrete; Void content.

Abstrak

Beton lolos air memiliki jaringan rongga yang saling terhubung sehingga air dapat meresap melewati material dan limpasan permukaan berpotensi dikurangi. Di sisi lain, tingkat porositas tersebut dapat memengaruhi kemampuan beton menahan beban. Penelitian ini mengevaluasi pengaruh panjang serat nilon terhadap kuat tekan, kuat tarik belah, dan kandungan rongga terukur ketika kadar serat dipertahankan tetap. Pengujian laboratorium melibatkan 36 benda uji silinder berukuran 150 mm × 300 mm, yang mewakili campuran kontrol tanpa serat serta campuran dengan serat nilon sepanjang 20, 30, dan 50 mm. Dosis serat ditetapkan sebesar 0,9 kg/m³ dan pengujian dilakukan pada umur 28 hari. Kuat tekan rata-rata campuran kontrol sebesar 19,43 MPa, sedangkan campuran serat 20, 30, dan 50 mm masing-masing mencapai 19,21, 18,89, dan 18,65 MPa. Nilai tersebut menunjukkan penurunan sebesar 1,13%, 2,78%, dan sekitar 4,01%. Kuat tarik belah tidak menunjukkan pola kenaikan atau penurunan yang berurutan; nilai rata-ratanya berturut-turut adalah 1,748, 1,746, 1,775, dan 1,675 MPa. Campuran serat 30 mm menghasilkan nilai rata-rata terukur tertinggi, yakni 1,775 MPa atau sekitar 1,54% di atas kontrol. Kandungan rongga terukur pada campuran kontrol adalah 26,16%, sementara campuran 20, 30, dan 50 mm masing-masing menghasilkan 26,32%, 37,89%, dan 27,39%. Dengan demikian, panjang serat berkaitan dengan respons yang berbeda pada setiap parameter yang diuji dalam batas kondisi eksperimen ini.

Kata Kunci:
Beton berpori; kandungan rongga; kuat tekan; panjang serat; serat nilon.

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1. INTRODUCTION

The growth of urban areas has expanded the coverage of impermeable surfaces, contributing to greater runoff volumes and additional demand on drainage infrastructure. These pressures have encouraged interest in construction materials that can support infiltration and stormwater control (Cui et al., 2024). Pervious concrete is produced with an open aggregate structure and interconnected voids, commonly using cement, coarse aggregate, and water with little or no fine aggregate. The pore network permits water movement through the hardened material, although the same structure can create a compromise between hydraulic function and mechanical strength (Anwar et al., 2022; Pedram et al., 2022).

Researchers have considered discrete fibers as a means of modifying pervious concrete behavior, particularly by bridging developing cracks and transferring stresses across them. Incorporating fibers into this material is not straightforward: the cement paste content is limited and the aggregate framework contains connected voids, so fiber dispersion and mixture consistency may influence the final pore structure. In their study of macrosynthetic fibers, Kevern et al. (2015) showed that fiber addition can affect pervious-concrete properties, emphasizing the relevance of fiber type and dosage when designing reinforced mixtures. Nylon, a synthetic polymer, has been examined as reinforcement in cement-based materials. Prior work has discussed its relationship with compressive and tensile strength, flexural behavior, cracking, and ductility (Khan et al., 2023). Fiber length is one geometric parameter that may alter contact with the cementitious matrix, crack bridging, and the ease with which fibers disperse during mixing. Longer fibers may provide a greater bridging length, but they can also be more difficult to distribute evenly. Research has explored synthetic fibers in pervious concrete and polyacrylonitrile fibers in similar mixtures (Long et al., 2025).

Nevertheless, evidence isolating the influence of nylon-fiber length on pervious concrete remains limited, particularly when dosage is held unchanged and measured void content is considered alongside mechanical properties. Studies that vary fiber type, quantity, and geometry simultaneously cannot readily attribute an observed response to length alone. The present experiment therefore maintained the dosage at 0.9 kg/m³ and varied fiber length, using plain pervious concrete as the reference mixture. Thirty-six cylinders (150 mm × 300 mm) were distributed among four mixtures, with three specimens assigned to each of the three tests per mixture. Testing at 28 days covered compressive strength, splitting tensile strength, and measured void content. The objective was to compare these responses while keeping the principal mixture conditions constant.

2. METHODOLOGY

2.1. Research Design

A controlled laboratory experiment was conducted to compare pervious concrete containing different nylon-fiber lengths. The four mixtures comprised an unreinforced control (BN) and three reinforced variants: F20, F30, and F50, containing fibers 20, 30, and 50 mm long, respectively. The fiber content in each reinforced mixture was fixed at 0.9 kg/m³, a level within the 0.6–0.9 kg/m³ range reported by (Ummahat et al., 2021). Holding dosage constant allowed fiber length to be examined as the principal variable. All mixtures were evaluated at 28 days for compressive strength, splitting tensile strength, and measured void content. A total of 36 cylindrical specimens, each measuring 150 mm in diameter and 300 mm in height, were prepared for the experimental investigation. The specimens were equally distributed among the four mixtures, with nine specimens allocated to each mixture. For each mixture, three replicate specimens were assigned to each of the three test procedures: compressive strength, splitting tensile strength, and void content determination. The unreinforced control mixture (BN) served as the reference for evaluating the effects of nylon-fiber incorporation and length. To ensure a consistent basis for comparison, the fiber dosage and principal mixture proportions were maintained across all fiber-reinforced mixtures. All tests were conducted at 28 days, and the measured results were compared among the mixtures to evaluate the influence of nylon-fiber length on the mechanical properties and void content of pervious concrete.

2.2. Materials

The mixtures were made from Portland Composite Cement (PCC), coarse aggregate, water, and nylon fiber; fine aggregate was not included. Crushed stone was used as the coarse aggregate, and its particle-size distribution was determined in accordance with ASTM C136/C136M (ASTM International, 2014). The

aggregate blend comprised 55% particles passing the 12.5 mm sieve and retained on the 9.5 mm sieve, together with 45% particles passing the 19 mm sieve and retained on the 12.5 mm sieve. Nylon strands were obtained by manually separating commercially available nylon rope and cutting the strands to the required lengths of 20, 30, or 50 mm. The fiber dosage in each reinforced mixture was 0.9 kg/m³.



a Coarse Aggregate b. Cement c Fiber

Figure 1. Constituent materials used in the production of pervious concrete: (a) coarse aggregate, (b) Portland Composite Cement, and (c) processed nylon fiber.

2.3. Mix Design

The mix proportions were designed with reference to the recommendations for pervious concrete provided in ACI 522R-10 American Concrete Institute (2010), with a target compressive strength of 25 MPa. Four formulations were produced: the plain control BN and mixtures reinforced with 20, 30, or 50 mm nylon fibers. Fiber content was fixed at 0.9 kg/m³ in the reinforced mixtures, and the other principal proportions were kept unchanged so that the comparison focused on fiber length. Table 1 lists the quantities used for one cubic metre of concrete.

Table 1. Mix proportions of pervious concrete for 1 m³

Material Code	Concrete without Fiber	Nylon Fiber Concrete (20 mm)	Nylon Fiber Concrete (30 mm)	Nylon Fiber Concrete (50 mm)
Water (kg)	180.17	180.17	180.17	180.17
Cement (kg)	415.5	415.5	415.5	415.5
CoarseAggregate (kg)	1242.07	1242.07	1242.07	1242.07
Nylon Fiber (kg)	0	0.9	0.9	0.9

2.4 Specimen Preparation

Materials were blended in a laboratory concrete mixer. For F20, F30, and F50, the cut nylon fibers were introduced at 0.9 kg/m³, after which water was added and mixing continued until the batch appeared uniform. Fresh concrete was placed in cylindrical molds 150 mm in diameter and 300 mm high and compacted using the procedure adopted for the experiment. Following curing, specimens were tested at 28 days. In total, 36 cylinders were produced: nine for each mixture. Within each mixture, three specimens were allocated to compressive testing, three to splitting tensile testing, and three to void-content measurement (n = 3 for each test and mixture). Table 2 summarizes this allocation.

Table 2. Distribution of Test Specimens by Mixture Type and Test Method

No	Mixture ID	Nylon Fiber Length (mm)	Fiber Dosage (kg/m³)	Compressive Strength	Splitting Tensile Strength	Void Content	Total
1	BN (Control)	0	0.00	3	3	3	9
2	F20	20	0.90	3	3	3	9
3	F30	30	0.90	3	3	3	9
4	F50	50	0.90	3	3	3	9
	Total			12	12	12	36

2.5 Aggregate Characterization

Before batching, coarse aggregate was tested to document its physical characteristics and assess its suitability for the mixtures. The measurements covered bulk density, specific gravity, particle-size distribution, and water absorption. Procedures followed the relevant ASTM methods, with the results considered alongside recommendations for pervious-concrete mixture design.

The measured aggregate properties were used to check the selected aggregate proportions and grading for the concrete batches. The characterization activities are illustrated in Figure 2.



a. Bulk density b. Specific gravity c. Sieve analysis

Figure 2. Aggregate characterization: (a) bulk density, (b) specific gravity, and (c) sieve analysis

2.6 Slump Test

Fresh-state consistency was assessed using a slump cone. After the cone was lifted, the mixture did not preserve a clearly defined conical profile, so a dependable slump height could not be recorded. The observation was therefore described qualitatively in terms of deformation and shape retention rather than reported as a numerical slump value.

2.7 Compressive Strength Test

At 28 days, compressive strength was measured on cylinders with a diameter of 150 mm and a height of 300 mm, following (ASTM International, 2003). Each specimen was centered in the compression-testing machine and loaded until failure. The peak load was recorded and used to calculate compressive strength according to Equation (1).

The compressive strength was calculated using:

$$fc = P/A \quad (1)$$

where:

Here, fc denotes compressive strength (MPa), P is the maximum load at failure (N), and A is the specimen's cross-sectional area (mm^2). The results were compared across the control and fiber-reinforced mixtures to examine how fiber length was associated with compressive resistance.

2.8 Splitting Tensile Strength Test

Splitting tensile strength was determined after 28 days of curing in accordance with ASTM International (2017), Cylinders measuring 150 mm in diameter and 300 mm in length were positioned horizontally in a compression-testing machine and loaded until fracture. The maximum load at failure was recorded for the calculation in Equation (2).

The splitting tensile strength was calculated using Equation (2):

$$\sigma tr = \frac{2P}{\pi L.D} \quad (2)$$

where:

σtr = splitting tensile strength (MPa),
P = maximum load recorded at specimen failure(N),
L = specimen length (mm), and
D= specimen diameter (mm).

Calculated splitting tensile strengths were compared for the plain control and the mixtures containing 20, 30, and 50 mm nylon fibers.

2.9. Void Content of Hardened Pervious Concrete

Hardened-concrete void content was assessed at 28 days using a mass-based method in accordance with ASTM C1754/C1754M (ASTM International, 2019). Three cylinders per mixture (150 mm diameter × 300 mm height) were prepared in a dry condition and weighed to obtain the dry mass, A. Each specimen was then immersed in water and its submerged mass, B, was recorded after trapped air had been released. Specimen volume (Vs) was calculated from the measured dimensions, and water density (ρw) was taken as approximately 1000 kg/m^3. All quantities were expressed in consistent SI units, and void content was calculated using Equation (3).

$$V^c = [(A - B)/(\varrho w\ V_s)] \times 100\% \quad (3)$$

Where :

Vc is the void content (%)
A is the dry mass of the specimen (kg)
B is the submerged mass of the specimen (kg)
ϱw is the density of water (kg/m³)
V_s is the volume of the specimen (m³).

The procedure was applied to the control (BN) and all reinforced mixtures (F20, F30, and F50). Three replicates per mixture were measured, giving 12 specimens for this test. The resulting values describe measured void content only; because this parameter does not directly measure hydraulic conductivity or infiltration rate, no permeability performance is inferred from it.

3. RESULTS AND DISCUSSION

3.1 Aggregate Characterization

Table 3 summarizes the physical properties measured for the coarse aggregate. Bulk density was 1.200 g/cm³; the saturated-surface-dry and oven-dry specific gravities were 2.658 and 2.582, respectively, and water absorption was 2.934%. These measurements were considered in selecting the aggregate blend for pervious concrete in reference to ACI 522R-10. Aggregate density, particle grading, specific gravity, and absorption can influence packing and the formation of voids in the hardened material.

Table 3. Coarse Aggregate Characteristics

No	Test Parameter	ACI 522R-10	Result
1	Bulk Density	1.119-1.480	1.200
	Specific Gravity		
2	a. SSD Specific Gravity	1.60-3.20	2.658
	b. Oven-Dry Specific Gravity	1.60-3.20	2.582
	Sieve Analysis		
3	12.5 mm (1/2 in)	0-100%	45%
	9.5 mm (3/8 in)	0-100%	55%
4	Water Absorption	0.2-4.0%	2.934%

The measured values fell within the reference intervals adopted in this study. Bulk density describes how the aggregate particles pack together, while specific gravity and absorption provide additional information about the aggregate's physical characteristics. The selected grading was intended to support a connected pore network. Taken together, the results were considered suitable for the experimental pervious-concrete mixtures.

3.2 Slump Test of Concrete

A numerical slump was not reported because the fresh concrete failed to retain a distinct cone shape after the mold was removed. Such behavior can occur in pervious mixtures, which typically rely on a coarse aggregate skeleton and contain relatively little paste. Although fibers may influence batch uniformity, their effects on workability were not quantified in this experiment. Figure 3 documents the test and the observed deformation.



a. Slump cone test procedure. b. Fresh concrete deformation after cone removal.

Figure 3. Slump test procedure and deformation behavior of the fresh pervious concrete mixture.

3.3 Compressive Strength

Compressive strength testing used cylindrical specimens measuring 150 mm × 300 mm, following ASTM C39/C39M. The specimen arrangement and loading procedure are shown in Figures 4 and 5.



a specimens b. compression test

Figure 4. Cylindrical specimens and compressive strength test: (a) specimens and (b) compression test

All compressive tests were conducted at 28 days in accordance with ASTM C39/C39M. The specimens had a diameter of 150 mm and a height of 300 mm; the measured strengths are summarized in **Figure 5.**

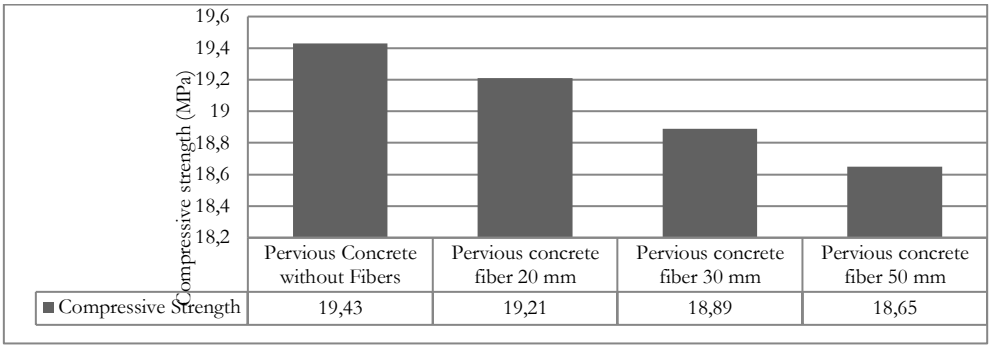


Figure 5. Compressive strength results of pervious concrete at 28 days

The control concrete produced the greatest mean compressive strength, at 19.43 MPa. The corresponding values for F20, F30, and F50 were 19.21, 18.89, and 18.65 MPa, equivalent to decreases of 1.13%, 2.78%, and approximately 4.01% relative to the control. Earlier Previous studies have discussed strength losses in nylon-fiber-reinforced concrete and have suggested that these losses may be related to fiber clustering and reduced workability, (Abhi et al., 2026). Here, dosage remained at 0.9 kg/m³; consequently, the downward trend with increasing fiber length could be related to dispersion, local clustering, or compaction differences. None of these mechanisms was measured directly, so they remain possible explanations rather than demonstrated causes. Other work has also highlighted the role of fiber configuration and distribution in concrete performance Sridhar et al. (2025); Khan et al. (2023) observed lower compressive strength at a nylon-fiber content of 2.5%, whereas Ahmad et al. (2021) reported gains up to about 1.5% fiber content followed by a decline at higher levels. These findings collectively suggest that fiber effects depend on dosage, geometry, and mixture characteristics.

3.4 Splitting Tensile Strength

Splitting tensile strength was measured at 28 days on 150 mm × 300 mm cylinders in accordance with ASTM International (2017), shown in Figure 6 shows the test arrangement.



a.Splitting tensile test setup. b Fractured concrete specimen.

Figure 6. a. Splitting tensile test set up b. Fractured concrete specimen

Table 4 provides the splitting tensile results for the mixtures containing different nylon-fiber lengths, together with the associated specimen measurements.

Table 4. Splitting tensile strength of nylon fiber-reinforced pervious concrete at 28 days

Nylon Fiber Length	Specimen ID	Specimen Mass (kg)	Cylinder Volume (m^3)	Unit Weight (kg/m^3)	Cylinder Diameter (mm)	Cylinder Length (mm)	Applied Load (kN)	Splitting Tensile Strength (N/mm^2)
	BN-01	10.780	0.0053	2033.962	150	300	125	1.77
	BN-02	11.130	0.0053	2100.000	150	300	123	1.74
	BN-03	10.790	0.0053	2035.849	150	300	122	1.73
	Mean	**10.900**	**0.0053**	**2056.604**	**150**	**300**	**124**	**1.75**
20 mm	F20-VC-01	9.905	0.0053	1868.868	150	300	112	1.59
	F20-VC-02	9.795	0.0053	1848.113	150	300	90	1.27
	F20-VC-03	11.650	0.0053	2198.113	150	300	168	2.38
	Mean	**10.450**	**0.0053**	**1971.698**	**150**	**300**	**123**	**1.75**
30 mm	F30-VC-01	10.220	0.0053	1928.302	150	300	130	1.84
	F30-VC-02	10.130	0.0053	1911.321	150	300	70	1.00
	F30-VC-03	12.225	0.0053	2306.604	150	300	176	2.49
	Mean	**10.858**	**0.0053**	**2048.742**	**150**	**300**	**125**	**1.77**
50 mm	F50-VC-01	11.180	0.0053	2109.434	150	300	144	2.04
	F50-VC-02	10.960	0.0053	2067.925	150	300	120	1.70
	F50-VC-03	11.525	0.0053	2174.528	150	300	91	1.29
	Mean	**11.222**	**0.0053**	**2117.296**	**150**	**300**	**118**	**1.67**

The measured splitting tensile response varied with fiber length rather than following a steady increase or decrease. Mean values were approximately 1.75 MPa for BN, 1.75 MPa for F20, 1.77 MPa for F30, and 1.67 MPa for F50. F30 had the highest measured mean, while F50 had the lowest. The lower result for F50 may relate to mixture uniformity or workability, but neither fiber distribution nor compaction was measured directly. Ratios of splitting tensile to compressive strength ranged from 8.98% to 9.40%, close to the 9–15%. Ahmad et al. (2021) also described a non-linear relationship between nylon-fiber dosage and splitting tensile performance, although fiber length—not dosage—was varied in the present experiment.

3.5 Measured Void Content

At 28 days, the measured void content differed among the mixtures. BN and F20 were similar, at 26.16% and 26.32%, respectively. F30 produced the highest value (37.89%), while F50 reached 27.39%. Since the experiment did not directly characterize fiber distribution, pore connectivity, or pore-size distribution, the reason for these differences cannot be confirmed. The results should therefore be interpreted as variations in measured void content, not as evidence of corresponding changes in permeability. Figure 7 presents the specimen preparation and mass measurements.



a. Pervious concrete specimens b. Dry mass measurement. c. Submerged mass measurement

Figure 7. Void content test procedure: (a) specimen preparation, (b) dry mass determination, and (c) submerged mass determination

The F30 mixture had the greatest mean measured void content (37.89%); the control mixture had the smallest value (26.16%). Individual dry-mass, submerged-mass, and calculated void-content results are provided in Table 5.

Table 5. *Dry Mass, Bulk Density, Submerged Mass, and Void Content of Hardened Pervious Concrete Specimens*

Specimen ID	Mixture	Specimen Volume, V_s (m^3)	A: Dry Mass (kg)	Bulk Density (kg/m^3)	B: Submerged Mass (kg)	ϱw (kg/m^3)	Void Content (%)
BN-01	BN	0.0053	11.170	2107.547	9.610	1000	29.43
BN-02	BN	0.0053	11.305	2133.019	10.205	1000	20.75
BN-03	BN	0.0053	11.595	2187.736	10.095	1000	28.30
Average	**BN**	**0.0053**	**11.357**	**2142.767**	**9.970**	**1000**	**26.16**
F20-VC-01	F20	0.0053	12.395	2338.679	11.295	1000	20.75
F20-VC-02	F20	0.0053	12.265	2314.151	10.850	1000	26.70
F20-VC-03	F20	0.0053	11.985	2261.321	10.315	1000	31.51
Average	**F20**	**0.0053**	**12.215**	**2304.717**	**10.820**	**1000**	**26.32**
F30-VC-01	F30	0.0053	11.860	2237.736	9.875	1000	37.45
F30-VC-02	F30	0.0053	11.990	2262.264	10.360	1000	30.75
F30-VC-03	F30	0.0053	12.405	2340.566	9.995	1000	45.47
Average	**F30**	**0.0053**	**12.085**	**2280.189**	**10.077**	**1000**	**37.89**
F50-VC-01	F50	0.0053	10.955	2066.981	9.395	1000	29.43
F50-VC-02	F50	0.0053	11.035	2082.075	9.545	1000	28.11
F50-VC-03	F50	0.0053	10.955	2066.981	9.650	1000	24.62
Average	**F50**	**0.0053**	**10.982**	**2072.012**	**9.530**	**1000**	**27.39**

3.6 Overall Influence of Nylon Fiber Length

At the constant nylon-fiber dosage of 0.9 kg/m^3, the four mixtures responded differently across the measured properties. Mean compressive strength decreased as fiber length increased: F20 reached 19.21 MPa, F30 reached 18.89 MPa, and F50 reached 18.65 MPa, compared with 19.43 MPa for BN. Relative reductions were 1.13%, 2.78%, and approximately 4.01%, respectively.

Splitting tensile strength followed a different pattern. Its mean rose slightly from 1.746 MPa for F20 to 1.775 MPa for F30, then fell to 1.675 MPa for F50. The F30 mean was about 1.54% higher than the control value of 1.748 MPa. Because this difference is small and no statistical significance test is reported here, it should be treated as a difference between measured means rather than proof of a significant improvement.

Void content also varied without a monotonic pattern: BN, F20, F30, and F50 had mean values of 26.16%, 26.32%, 37.89%, and 27.39%, respectively. The F30 mixture showed the largest measured void content, whereas BN and F20 were close. The distinct patterns in compressive strength, splitting tensile strength, and void content indicate that fiber length did not affect all measured properties in the same way.

Within the mixture proportions, fiber dosage, and curing age used in this experiment, longer nylon fibers were associated with progressively lower compressive strength, while splitting tensile strength and measured void content showed non-monotonic variation. Fiber dispersion, pore connectivity, pore-size distribution, and hydraulic permeability were not directly measured; therefore, the mechanisms behind the observed trends cannot be established from these data. Interpretation should remain limited to the properties and conditions examined.

4. CONCLUSION

This experiment examined the 28-day properties of pervious concrete reinforced with nylon fibers of different lengths at a fixed dosage of 0.9 kg/m^3. Mean compressive strength declined from 19.43 MPa in the control to 18.65 MPa in the mixture containing 50 mm fibers. The 30 mm mixture gave the highest measured mean splitting tensile strength (1.775 MPa) and void content (37.89%). No tested fiber length was best for every property, and none of the mixtures attained the target compressive strength of 25 MPa. Further work should include more replicates, appropriate statistical comparisons, direct permeability measurements, and characterization of pore structure and fiber distribution.

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