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Nylon Fibre Reinforcement of Lightweight Foamed Concrete: Effects of Specific Gravity and Fibre Content on Compressive, Splitting Tensile, and Flexural Behaviour

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ABSTRACT

Foamed concrete is attractive for earthquake-prone regions because of its low self-weight, but its low tensile capacity and brittle failure limit its structural use. This study examines how nylon fibre (25 mm long, 0.35 mm in diameter) modifies the compressive, splitting tensile, and flexural strength of foamed concrete. A 3 × 3 factorial programme combined three specific gravities (SG 1.2, 1.4, and 1.6) with three fibre contents (0.5%, 1.0%, and 1.5% by mass) at a water–cement ratio of 0.4, and 81 specimens were tested at 28 days. Results were compared with fibre-free foamed concrete of the same SG and analysed using two-way analysis of variance and multiple linear and polynomial regression. Nylon fibre increased compressive strength by 38–153%, splitting tensile strength by 42–136%, and apparent flexural strength by 210–694%, with the highest mean values of 24.7, 3.15, and 7.27 MPa, respectively. Fibre content alone did not significantly affect compressive strength ($F = 3.35 < 3.55$) but significantly affected tensile and flexural strength, and its interaction with SG was significant for all three properties. Polynomial models ($R^2 = 0.74–0.84$) described the data better than linear models ($R^2 = 0.64–0.73$). Flexural strength was nearly independent of compressive strength ($r = 0.01$), and nylon outperformed ijuk and coir fibres in flexure. The findings support nylon-fibre foamed concrete as a promising lightweight material, pending structural-element and durability tests.

Keywords: *Foamed Concrete, Nylon Fibre, Specific Gravity, Flexural Strength, Two-Way ANOVA, Polynomial Regression*

1. INTRODUCTION

Reducing the self-weight of a structure is one of the most direct ways of lowering the inertial forces that earthquakes impose on buildings, which makes lightweight concrete an attractive option for seismically active regions such as Aceh [1]. Foamed concrete, produced by blending a preformed foam into a cement paste or mortar, is a particularly versatile member of this family [2]. Its density can be tuned between roughly 400 and 1,800 kg/m³ [3], and it combines low self-weight with useful thermal insulation and good flowability [4]. These attributes explain its growing use in masonry walls, infill panels, and other non-structural or semi-structural elements [5].

The same air voids that make foamed concrete light also make it weak and brittle. Strength falls as foam volume increases [3], [6], and the porous matrix offers little resistance to crack propagation, so tensile and flexural capacities are especially poor. These drawbacks, together with low toughness, have restricted the use of foamed concrete in load-bearing applications [4], [7].

Dispersed fibres are the most common remedy. Polypropylene, polyvinyl alcohol (PVA), polyformaldehyde, and macro-synthetic fibres have raised the tensile and flexural strength and the toughness of foamed concrete over a range of densities [8], [9], while natural fibres such as oil palm

and sugarcane bagasse offer a renewable alternative [10], [11]. The benefit is, however, dose dependent. In polyformaldehyde-fibre foamed concrete, strength gains reached an optimum at a fibre content of 3% [3], and the optimum content of polypropylene fibre has been shown to depend on the density of the matrix [9].

Nylon (polyamide) is an attractive but comparatively under-studied fibre. It combines high tensile strength with good elasticity, is inexpensive, and is widely available as cord or thread. In ordinary concrete, straight nylon fibres have raised compressive, splitting tensile, and flexural strength by roughly 12–16% [12]. For foamed concrete, evidence is limited to a few dose-specific investigations, such as a recent study at Universitas Syiah Kuala that tested a single fibre content (1%) at three specific gravities [13].

Three gaps therefore remain. First, the response of foamed concrete to nylon fibre across a range of densities and fibre contents has not been mapped in a complete factorial design. Second, the interaction between density and fibre content, which determines whether a given dose helps or hurts, is rarely tested statistically. Third, relationships among the compressive, splitting tensile, and flexural strengths of fibre-reinforced foamed concrete are poorly established, which hampers prediction-based design [7], [14].

This study investigates nylon-fibre foamed concrete in a 3 × 3 factorial programme combining three specific gravities (SG 1.2, 1.4, and 1.6) with three fibre contents (0.5%, 1.0%, and 1.5% by mass). The objectives are to (i) quantify the effect of nylon fibre on compressive, splitting tensile, and flexural strength relative to fibre-free foamed concrete; (ii) test the significance of SG, fibre content, and their interaction by two-way analysis of variance (ANOVA); (iii) develop and compare linear and polynomial regression models; and (iv) benchmark nylon against ijuk (sugar palm) and coir fibres previously tested in the same laboratory. The contribution lies in the combination of a complete factorial dataset, statistically validated models, and an explicit examination of the relationships among the three strengths.

2. LITERATURE REVIEW

2.1 *Foamed Concrete and Density Control*

Foamed concrete is a cementitious composite in which stable air bubbles are introduced through a preformed foam [4], [5], and its potential as a structural material has long been recognised [15]. Because it contains no coarse aggregate, its density is governed mainly by foam volume: more foam lowers density but also reduces strength and alters the pore structure [7], [1], and compressive strength is further affected by curing conditions, cement type, and foaming agent [16]. In Indonesian practice, unit weights of 800–1,400 kg/m³ fall within the range specified for structural lightweight concrete in SNI 03-3449-2002 [17]; the SG 1.2 and 1.4 mixtures examined here lie inside this range, whereas SG 1.6 lies just above it. Binder composition and fillers also influence strength [1], [18], [19], but with a fixed binder system the density–strength relationship remains the first-order control.

2.2 Fibre-Reinforced Foamed Concrete

Fibres act as bridging reinforcement across microcracks, and the magnitude of the benefit depends on fibre type, geometry, dosage, and matrix density. Layers of micro-synthetic fibre raised the flexural and splitting tensile strength of foamed concrete by

several hundred per cent at densities of 600–1,600 kg/m³, for example by up to 507% in splitting tension at 600 kg/m³ [22]. PVA fibres improved the pre-crack flexural response and the splitting tensile strength by modifying the pore structure, whereas fibre length and content governed post-crack behaviour [20], and hybrid PVA–polypropylene fibres improved flexural toughness [21]. Under compression, low-density polypropylene foamed concrete showed strain hardening while higher-density mixtures failed by strain softening, and the optimum fibre dosage increased with density [9]. Macro-polypropylene fibre at 0.3% raised the compressive and splitting tensile strength of bio-based lightweight foamed concrete by about 23% and 38% [22], and twisted macro-synthetic fibres enhanced flexural and tensile strength [8]. Natural fibres have been explored as renewable reinforcement [10], with treated sugarcane bagasse fibre giving optimum strength at a dosage of 4% [11].

Nylon has been studied less. In ordinary concrete, straight and flattened-end nylon fibres at 0.5–1.5% dosage increased compressive, splitting tensile, and flexural strength by up to about 12%, 14%, and 16%, with fibre shape and aspect ratio controlling the bond [12]. In foamed concrete, nylon fibre at 1% of the mix volume raised compressive strength by 11–42% across SG 1.2–1.6, compared with 4–69% for polypropylene fibre [13].

2.3 Statistical Modelling of Strength

The strength of foamed concrete depends on several interacting factors, and regression models offer a practical route to prediction. Polynomial regression has been used to relate mix variables to the strength of foamed concrete [7] and of eco-friendly concrete [14], and artificial neural networks have been applied to glass- and basalt-fibre concrete [23]. In parallel, constitutive models describe the compressive stress–strain curve of fibre-reinforced foamed concrete in stages [24], and data-driven frameworks extend uniaxial models to fibre-reinforced concrete in general [25]. For a small experimental programme with two controlled factors, two-way ANOVA combined with polynomial regression remains a transparent and interpretable approach and is adopted here.

3. METHODS

3.1 Materials and Mixture Design

The work was carried out in the Construction and Building Materials Laboratory, Department of Civil Engineering, Universitas Syiah Kuala. Type I Portland cement was used after visual inspection for intact packaging and the absence of lumps, and clean laboratory water free of mud, oil, and deleterious salts was used for mixing and curing. A synthetic foam agent, a type whose pore structure differs from that produced by protein-based agents [26], diluted with water at a ratio of 1:30 and expanded in a foam generator, produced bubbles about 1 mm in diameter. Nylon fibre was prepared by unravelling nylon cord and cutting it to a length of about 25 mm; its diameter and specific gravity were measured in the laboratory (Fig. 1).

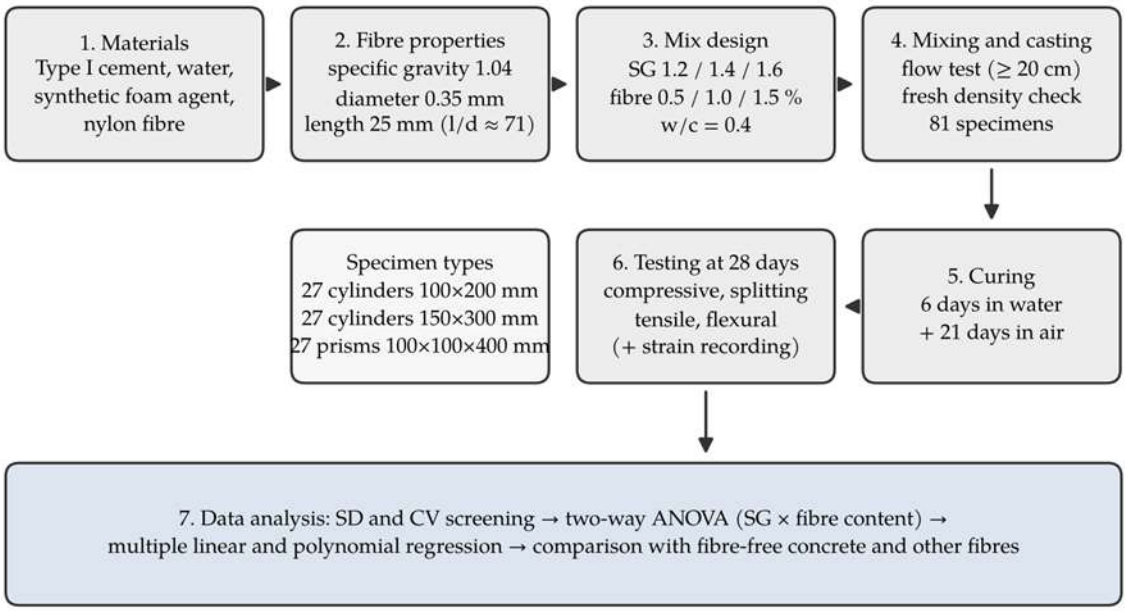


Figure 1. Experimental programme of the study.

Nine mixtures combined three target specific gravities (SG 1.2, 1.4, and 1.6, corresponding to fresh densities of 1,200, 1,400, and 1,600 kg/m³) with three fibre contents (0.5%, 1.0%, and 1.5% of the target fresh mass). The water–cement ratio was fixed at 0.4. Because the pastes did not reach the target flow at this ratio, a superplasticiser at 1–3% of the cement mass was added to obtain a flow of at least 20 cm. The resulting proportions per cubic metre are given in Table 1. Fibre content is expressed on a mass basis, so that, for example, 0.5% fibre corresponds to 6 kg/m³ at SG 1.2.

Table 1. Mixture proportions of nylon-fibre foamed concrete per cubic metre (water–cement ratio = 0.4).

SG	Nylon fibre (%)	Cement (kg/m³)	Water (kg/m³)	Nylon (kg/m³)	Foam (L/m³)
1.2	0.5	852.86	341.14	6.00	382.34
	1.0	848.57	339.43	12.00	379.65
	1.5	844.29	337.71	18.00	376.95
1.4	0.5	995.00	398.00	7.00	279.40
	1.0	990.00	396.00	14.00	276.25
	1.5	985.00	394.00	21.00	273.11
1.6	0.5	1137.14	454.86	8.00	176.45
	1.0	1131.43	452.57	16.00	172.86
	1.5	1125.71	450.29	24.00	169.27

Source: Mixture design calculations (this study).

Water and cement were mixed first and the flow was measured. The superplasticiser and nylon fibres were then added and, finally, the foam, so that the bubbles were not broken by the fibres. The fresh density of each batch was checked in a 1-L container, and flow was monitored at intervals up to 60 min after mixing. Each of the nine mixtures was cast in a separate batch.

3.2 Specimens, Curing, and Testing

Three replicates of each mixture were prepared for each test: cylinders of 100 × 200 mm for compression, cylinders of 150 × 300 mm for splitting tension, and prisms of 100 × 100 × 400 mm for flexure, giving 27 specimens per test and 81 in total. Specimens were cured in water for 6 days at 16–

27 °C and then air-dried for 21 days, giving a test age of 28 days. To examine strength development, additional compression specimens of the SG 1.2 mixture with 0.5% fibre were tested at 7 and 14 days.

Compression, splitting, and flexural tests followed ASTM C39/C39M [27] [28], ASTM C496/C496M [28], and ASTM C78/C78M [29], respectively, using a 20-t universal testing machine. The prisms were supported on a 300 mm span and loaded at the third points until failure. Axial strain in the compression tests was recorded with two displacement transducers connected to a data logger, with readings at every 1 t load increment. The strengths were calculated as

$$f'_c = P/A \qquad (1)$$

$$f_t = 2P/(\pi LD) \qquad (2)$$

$$f_r = PS/(bh^2) \qquad (3)$$

where P is the maximum load, A the cross-sectional area, L and D the length and diameter of the cylinder, S the span, and b and h the width and depth of the prism. The quantities f'_c, f_t, and f_r denote the compressive, splitting tensile, and flexural (apparent modulus of rupture) strengths, respectively.

3.3 Data Analysis

Fibre-free control values for each SG were taken from earlier tests in the same laboratory (Mahlil, 2010), so that changes could be expressed as percentages; the same work and a companion study (Ismatullah, 2010) supplied the ijuk and coir values used for comparison in Section 4.9. Because these controls were not cast concurrently with the nylon mixtures, the percentage changes are indicative (Section 4.10). Strength classes of lightweight concrete follow Neville [30], and specimen variability was screened with the coefficient of variation (CV) using Troxell's laboratory-quality criteria. The effects of SG (factor A) and fibre content (factor B) were tested by a two-way fixed-effects ANOVA with three replicates per cell at $\alpha = 0.05$. Multiple linear and second-order polynomial regression models were then fitted,

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1^2 + \beta_4 X_2^2 + \beta_5 X_1 X_2 \qquad (4)$$

where Y is the strength in MPa, X_1 is SG, and X_2 is the fibre content in per cent; the linear model contains only the first three terms. Model adequacy was assessed by the F-test of regression and the coefficient of determination (R^2) [16]. All ANOVA and regression results reported below were recomputed from the specimen-level data.

4. RESULTS AND DISCUSSION

4.1 Fibre Properties and Fresh Behaviour

The nylon fibres had a mean diameter of 0.35 mm and a specific gravity of 1.04. With a length of 25 mm, the aspect ratio (l/d) is about 71, a magnitude that makes uniform dispersion in fresh foamed concrete a concern. As Table 1 shows, a higher SG required less foam (from about 380 L/m³ at SG 1.2 to about 170 L/m³ at SG 1.6) and more cement (from about 844–853 to 1,126–1,137 kg/m³); within each SG group, cement and foam decreased slightly as the fibre mass increased because the total mass per cubic metre was fixed.

All cement–water pastes had a flow below 20 cm, and the superplasticiser raised the flow to 20 cm (SG 1.2 at 0.5% and 1.5% fibre, and SG 1.4 at all fibre contents) and 21 cm (SG 1.6 at 1.5% fibre), the largest values within each SG group. Measured fresh densities were 1,206–1,250, 1,402–1,423, and 1,635–1,667 kg/m³ against targets of 1,200, 1,400, and 1,600 kg/m³, that is, within 4.2% of the design value. Flow declined gradually with time (Fig. 2) to about 64–75% of the initial value after 60 min. The decline was similar in all mixtures, with a slight tendency to be larger in the cement-rich mixtures, so that casting within about 30 min of mixing is advisable.

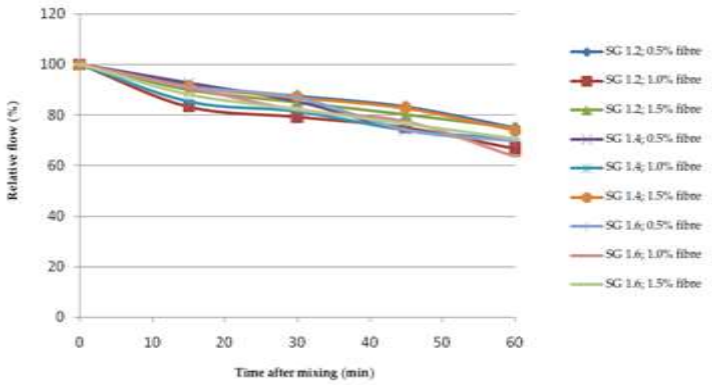


Figure 2. Relative flow of fresh nylon-fibre foamed concrete during the first 60 min after mixing (percentage of the initial flow).

4.2 Compressive Strength

Table 2 and Fig. 3a summarise the 28-day strengths. Nylon fibre raised the mean compressive strength above that of fibre-free foamed concrete in all nine mixtures, by 38–46% at SG 1.2, 57–153% at SG 1.4, and 73–142% at SG 1.6. The largest relative gain (153%) occurred at SG 1.4 with 0.5% fibre (21.1 MPa against 8.3 MPa), and the highest absolute strength (24.7 MPa) was obtained at SG 1.6 with the same fibre content.

Table 2. Mean strength of nylon-fibre foamed concrete at 28 days and change (Δ) relative to fibre-free foamed concrete of the same SG (n = 3 per mixture).

SG	Nylon (%)	f′c		ft		fr	
		MPa	Δ (%)	MPa	Δ (%)	MPa	Δ (%)
1.2	0 (control)	6.75	–	0.68	–	0.89	–
	0.5	9.33	+38	1.28	+88	2.96	+233
	1.0	9.86	+46	1.60	+136	5.15	+478
	1.5	9.43	+40	1.48	+119	7.07	+694
1.4	0 (control)	8.34	–	1.23	–	1.24	–
	0.5	21.11	+153	2.69	+118	4.22	+241
	1.0	19.34	+132	2.37	+92	7.27	+489
	1.5	13.07	+57	2.41	+96	7.25	+486
1.6	0 (control)	10.19	–	1.43	–	1.41	–
	0.5	24.66	+142	2.04	+42	4.38	+210
	1.0	17.61	+73	2.79	+95	5.50	+290
	1.5	23.58	+131	3.15	+119	7.08	+402

Source: Experimental data (this study); fibre-free control values from earlier tests in the same laboratory (Mahlil, 2010).

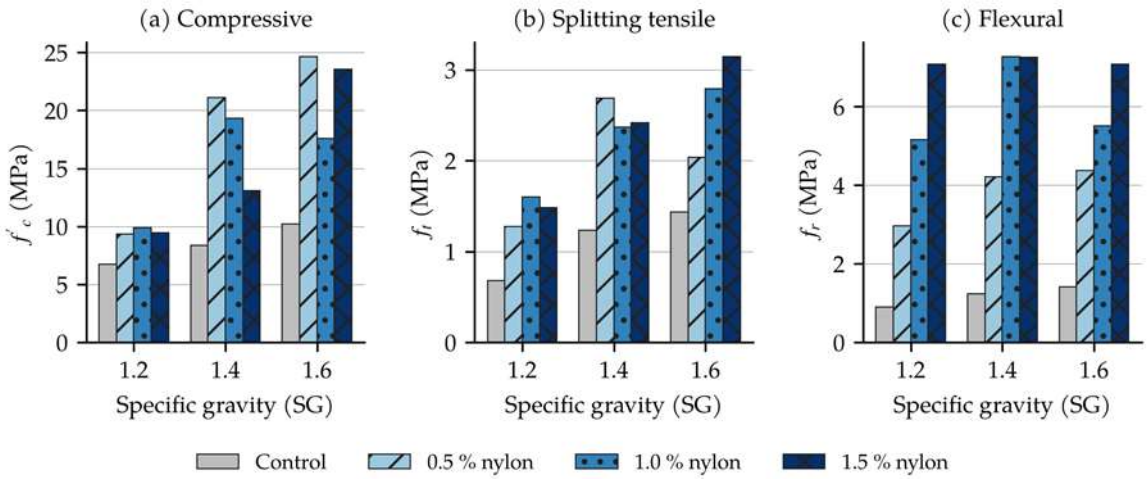


Figure 3. Mean 28-day (a) compressive, (b) splitting tensile, and (c) flexural strength of foamed concrete with and without nylon fibre.

Compressive strength was not a monotonic function of fibre content. In the two denser series the lowest dose performed best, and strength fell by 38% between 0.5% and 1.5% fibre at SG 1.4 and by 29% between 0.5% and 1.0% at SG 1.6, before partly recovering at 1.5% (23.6 MPa). At SG 1.2, strength was essentially insensitive to fibre content (9.3–9.9 MPa). This behaviour is consistent with the ANOVA result that fibre content alone does not significantly affect compressive strength (Section 4.8) and with the view that fibres act mainly on tensile and post-peak behaviour, whereas the optimum fibre content depends on matrix density and fibre type [7], [11].

Using the conventional strength classes of lightweight concrete (moderate strength, 7–17 MPa; structural, above 17 MPa), all SG 1.2 mixtures and the SG 1.4 mixture with 1.5% fibre fall in the moderate-strength class, whereas the remaining five mixtures (17.6–24.7 MPa) qualify as structural lightweight concrete. For comparison, a study at the same university reported 6.0, 11.7, and 17.2 MPa for 1% nylon at SG 1.2, 1.4, and 1.6 [15], which is lower than the 9.9, 19.3, and 17.6 MPa obtained here; differences in fibre geometry and mixture details, which were not controlled across the two studies, probably contribute.

4.3 Strength Development and Stress–Strain Behaviour

For the SG 1.2 mixture with 0.5% fibre, the relative compressive strength was 0.533 at 7 days and 0.612 at 14 days (28 days = 1.000), compared with 0.65 and 0.81 for ordinary concrete (Fig. 4). The slower early gain indicates that this fibre-reinforced foamed concrete reaches a larger share of its 28-day strength later. Whether this arises from the fibre, the high air content, or the curing regime cannot be separated from a single mixture, and tests at later ages would show whether strength continues to increase beyond 28 days.

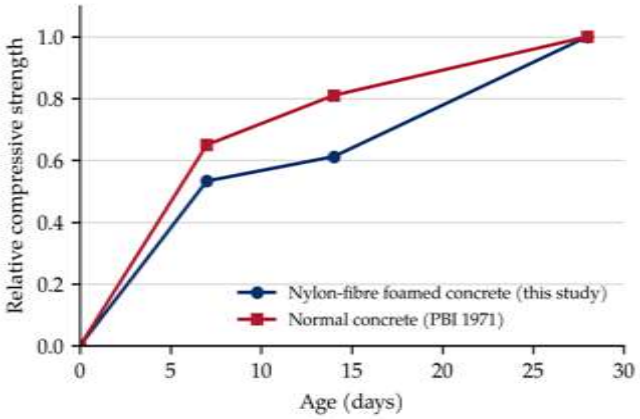


Figure 4. Relative compressive strength development of nylon-fibre foamed concrete (SG 1.2, 0.5% fibre) compared with ordinary concrete.

The stress–strain curves recorded in the compression tests (Fig. 5) show that denser mixtures reached higher peak stresses, with peak strains of the order of 10^{-3} or below. Because stress was recorded in load increments up to the peak, the descending branch, where fibres are expected to have their greatest effect, was not captured; displacement-controlled tests are therefore recommended to quantify the toughness that fibres are known to impart to foamed concrete [10], [11] and to calibrate staged constitutive models [25].

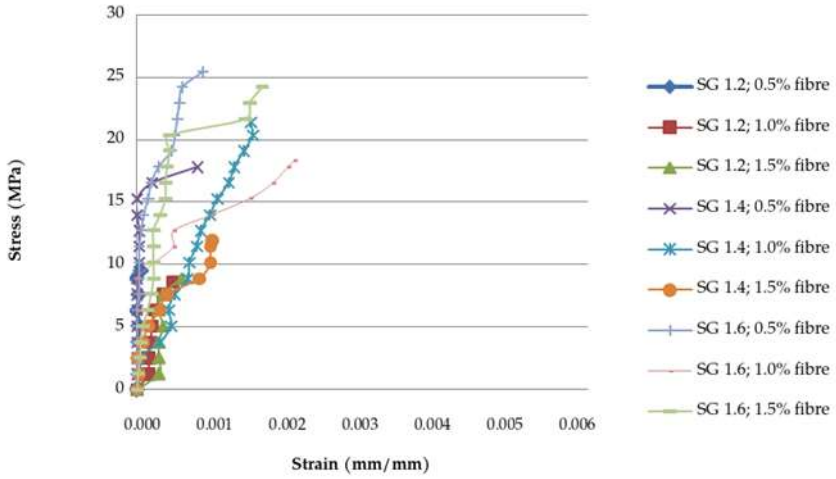


Figure 5. Compressive stress–strain curves of nylon-fibre foamed concrete for all SG and fibre-content combinations.

4.4 Splitting Tensile Strength

Splitting tensile strength increased in every mixture (Table 2 and Fig. 3b), by 88–136% at SG 1.2, 92–118% at SG 1.4, and 42–119% at SG 1.6. The largest relative gain (136%) was found at SG 1.2 with 1.0% fibre (1.60 MPa), whereas the highest absolute value (3.15 MPa) was found at SG 1.6 with 1.5% fibre. The three SG groups responded differently to the dose: at SG 1.6 the strength rose steadily with fibre content (2.04, 2.79, and 3.15 MPa), at SG 1.2 it peaked at 1.0%, and at SG 1.4 it was highest at the lowest dose (2.69 MPa) and varied little between 1.0% and 1.5% (2.37 and 2.41 MPa). The significant SG × fibre interaction (Section 4.8) quantifies this dependence, which echoes reports that the optimum fibre content of foamed concrete shifts with density [11] and that the tensile benefit is linked to fibre–pore interaction [9].

4.5 Flexural Strength

The strongest response was observed in flexure (Table 2 and Fig. 3c). The mean apparent flexural strength rose from 0.89–1.41 MPa in fibre-free concrete to 2.96–7.27 MPa with nylon, increments of 210–694%. At SG 1.2 and 1.6 it increased steadily with fibre content (2.96, 5.15, and 7.07 MPa at SG 1.2; 4.38, 5.50, and 7.08 MPa at SG 1.6), whereas at SG 1.4 it reached a plateau at 1.0% fibre (7.27 MPa) that was unchanged at 1.5% (7.25 MPa). The pattern agrees with a crack-bridging mechanism: unlike compression, flexure is governed by the ability of fibres to carry stress across the first cracks [9], [22].

Two cautions apply. First, the ratio of flexural to compressive strength reached 0.75 at SG 1.2 with 1.5% fibre (7.07/9.43 MPa), far above the values associated with unreinforced concrete. This suggests that the peak load of the fibre-reinforced prisms reflects post-cracking resistance rather than first-crack strength, so the values are best read as apparent strengths obtained from the elastic formula in Eq. (3); load–deflection records would be needed to separate the first-crack and peak loads. Second, the fibre-free reference values come from earlier tests, so the percentage increases are indicative.

4.6 Failure Patterns

Fibre-free specimens fail abruptly: cylinders in compression disintegrate, splitting cylinders separate into two halves, and prisms break into two pieces at peak load. The nylon-reinforced specimens, in contrast, developed distributed cracks and remained intact. Compression cylinders cracked over their surface without disintegrating, splitting cylinders developed a single central crack, and the prisms continued to carry load as the crack widened without separating. This shift from brittle to more ductile failure is the visible signature of fibre bridging and agrees with the toughness gains reported for synthetic-fibre foamed concrete [10], [11].

4.7 Relationships among the Strengths

Figure 6 relates the three strengths using all 27 specimen sets. Compressive and splitting tensile strength were moderately correlated (r = 0.66), with a regression of ft = 0.068f′c + 1.085 (MPa); the low gradient and the large positive intercept reflect the contribution of the fibres to tensile capacity. Flexural strength was essentially uncorrelated with compressive strength (r = 0.01) and only weakly correlated with splitting tensile strength (r = 0.35). Such decoupling is expected where the fibres, rather than the matrix, govern flexure, and it contrasts with the strong coupling assumed in design expressions based on √f′c.

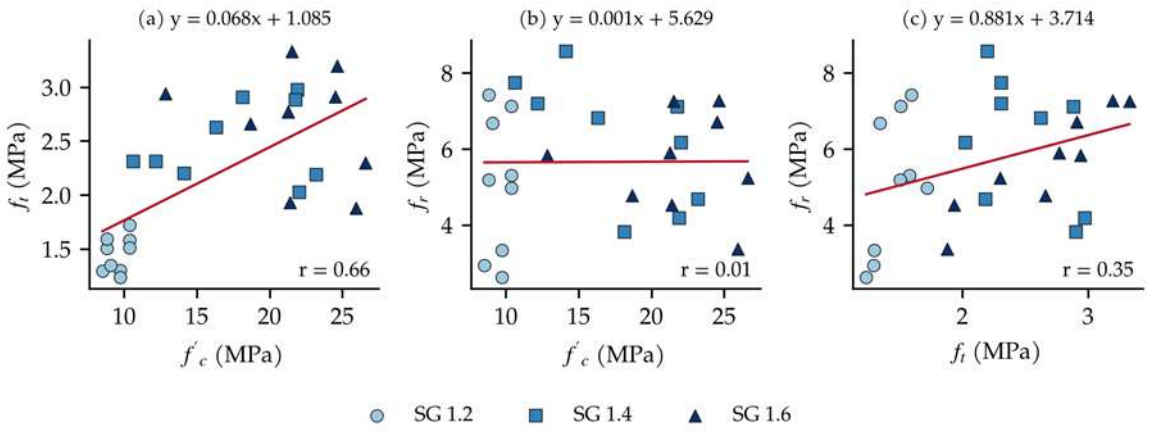


Figure 6. Relationships between (a) compressive and splitting tensile, (b) compressive and flexural, and (c) splitting tensile and flexural strength (n = 27).

Expressed relative to $\sqrt{f'_c}$, the splitting tensile strength ranged from 0.37 to 0.82 and the flexural strength from 0.66 to 2.50 (MPa units), against commonly adopted values for plain lightweight concrete of 0.34–0.51 and 0.51–0.68, respectively. Expressions calibrated for plain lightweight concrete therefore under-predict the tensile response of nylon-reinforced foamed concrete in most cases, and relations calibrated for fibre-reinforced material are needed.

4.8 Statistical Analysis

The two-way ANOVA (Table 3) shows that SG had a significant effect on all three strengths. Fibre content had no significant effect on compressive strength (F = 3.35 < Fcrit = 3.55) but significantly affected splitting tensile and flexural strength, and the SG × fibre interaction was significant for all three. Fibre content was by far the dominant factor in flexure, accounting for about 73% of the total variation, whereas SG dominated compression (about 69%) and splitting tension (about 69%).

Table 3. Two-way ANOVA of compressive, splitting tensile, and flexural strength (α = 0.05).

Source	df	F-calculated			Fcrit
		f′c	ft	fr	
SG (A)	2	47.84*	59.72*	7.98*	3.55
Nylon content (B)	2	3.35 ns	4.52*	63.24*	3.55
Interaction (A × B)	4	4.79*	6.57*	3.25*	2.93
Error	18	–	–	–	–
Total	26	–	–	–	–

*Note: * significant; ns not significant. Source: ANOVA recomputed from specimen-level data (this study).*

Both regression families were significant (Table 4), and the second-order polynomial improved the fit for every property. The fitted polynomial models (MPa) are

$$f'_c = -125.08 + 180.50X_1 - 8.95X_2 - 52.33X_1^2 + 5.04X_2^2 - 2.95X_1X_2 \quad (5)$$

$$f_t = -20.51 + 31.22X_1 - 2.16X_2 - 10.88X_1^2 - 0.32X_2^2 + 2.26X_1X_2 \quad (6)$$

$$f_r = -49.14 + 67.14X_1 + 12.08X_2 - 22.20X_1^2 - 1.94X_2^2 - 3.52X_1X_2 \quad (7)$$

Table 4. Comparison of linear and second-order polynomial regression models (α = 0.05).

Strength	Model	R^2	Fcalc	df	Fcrit
f′c	Linear	0.700	27.93	2, 24	3.40
	Polynomial	0.735	11.63	5, 21	2.68
ft	Linear	0.638	21.11	2, 24	3.40
	Polynomial	0.799	16.68	5, 21	2.68
fr	Linear	0.732	32.70	2, 24	3.40
	Polynomial	0.843	22.56	5, 21	2.68

Source: Regression analysis of specimen-level data (this study).

The models are valid only within the tested ranges (SG 1.2–1.6; 0.5–1.5% fibre) and, with three replicates per cell, should be regarded as descriptive. They nevertheless capture the nonlinear and interacting effects that linear models miss, in line with the benefits of polynomial regression reported for foamed concrete and other concretes [3], [16].

4.9 Comparison with Ijuk and Coir Fibres

Table 5 compares nylon with ijuk fibre and coir fibre tested at the same SG and fibre contents in the same laboratory (Mahlil, 2010; Ismatullah, 2010). In flexure, nylon was clearly superior in every comparable mixture; for example, at SG 1.4 the flexural strength with nylon was 4.2–7.3 MPa, against 1.4–2.6 MPa with ijuk and 1.1–1.9 MPa with coir. In compression and splitting tension the picture was mixed. Nylon gave the higher value in most mixtures, but ijuk was higher in compression at SG

1.2 with 0.5% fibre, at SG 1.4 with 1.5% fibre, and at SG 1.6 with 0.5% and 1.0% fibre, and ijuk or coir was higher in splitting tension at SG 1.6 with 0.5% and 1.0% fibre. Because the comparison is across separate studies, it indicates a trend rather than a controlled ranking.

Table 5. Mean strength of foamed concrete reinforced with nylon, ijuk, and coir fibre at the same SG and fibre contents.

SG	Fibre (%)	f'c (MPa)			ft (MPa)			fr (MPa)		
		Nylon	Ijuk	Coir	Nylon	Ijuk	Coir	Nylon	Ijuk	Coir
1.2	0.5	9.33	10.65	–	1.28	0.74	–	2.96	1.49	–
	1.0	9.86	7.05	–	1.60	0.96	–	5.15	1.67	–
	1.5	9.43	7.89	–	1.48	0.97	–	7.07	1.83	–
1.4	0.5	21.11	10.86	8.97	2.69	1.51	1.38	4.22	1.35	1.13
	1.0	19.34	16.04	9.61	2.37	1.64	1.46	7.27	1.92	1.64
	1.5	13.07	14.05	10.65	2.41	1.98	1.54	7.25	2.58	1.92
1.6	0.5	24.66	26.68	13.19	2.04	2.33	2.26	4.38	1.82	1.52
	1.0	17.61	25.59	15.91	2.79	2.90	2.27	5.50	2.15	2.25
	1.5	23.58	16.55	16.80	3.15	3.01	2.38	7.08	3.00	3.05

Note: Coir fibre was not tested at SG 1.2. Source: Nylon, this study; ijuk and coir, earlier tests in the same laboratory (Mahlil, 2010; Ismatullah, 2010).

4.10Practical Implications and Limitations

The results indicate that nylon fibre at 0.5–1.5% turns brittle, low-strength foamed concrete into a material of structural lightweight class at SG 1.4–1.6, with markedly improved tensile and flexural performance. For applications in which self-weight and crack control both matter, such as wall panels and lightly loaded slabs in seismic regions, a dose of about 1.0% at SG 1.4 appears to balance the results: it retained 19.3 MPa in compression and gave the plateau flexural strength (7.27 MPa), whereas 1.5% brought no further flexural gain and reduced compressive strength to 13.1 MPa. The study is limited by non-concurrent controls, three replicates per mixture, a single fibre length, a single test age, and the absence of post-peak, durability, and thermal data; these should be addressed before the material is specified for structural elements.

CONCLUSION

Nylon fibre improved the compressive, splitting tensile, and flexural strength of foamed concrete at SG 1.2–1.6, with relative gains of 38–153%, 42–136%, and 210–694%, respectively, and with five of the nine mixtures reaching the structural lightweight class (above 17 MPa). Compressive strength depended mainly on SG, and fibre content alone was not significant, whereas fibre content strongly governed tensile and flexural strength, and the SG × fibre interaction was significant for all three properties. Second-order polynomial regression described the data better (R^2 = 0.74–0.84) than linear regression (R^2 = 0.64–0.73), flexural strength was almost independent of compressive strength, and nylon was clearly more effective in flexure than ijuk or coir fibre. Nylon-fibre foamed concrete is therefore a promising lightweight material for earthquake-prone regions. Future work should include concurrent fibre-free controls, displacement-controlled tests to capture post-peak toughness, other fibre lengths and ages, durability and thermal properties, and tests on structural elements.

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